An Experimental Study on Coated Reinforcement Bars and Recycled Aggregate in Concrete with Different Exposures

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***Abstract-* The objective of this study is to compare the ultimate load carrying capacity of conventional reinforced concrete beams with that of investigations specimen incorporated with coated reinforcement and partially with recycled aggregate and quarry dust. A noval technique of coated reinforcement delays the onset of corrosion with enhanced durability of structures results show that not even a film of corrosion (while rust) can be seen in the investigation specimen. Main aim of this work will be on the ultimate load carrying capacity of beams. The ultimate load carrying capacity of beams are influenced by various parameters such as material properties, geometry, influence of environments, cover to the reinforcement, were ability permeability, compaction, consolidation, water cement ratio and so on. Those works investigates on the incorporation of the coated reinforcement, partially with recycled aggregates and the quarry dust partially with admixtures in reinforced concrete beams. The usage of coating technique for reinforcement is a widely accepted innovative technique for reducing corrosion in concrete structure. Epoxy coated and Hot dip galvanizing is the two popular methods of coating to reinforcement. The galvanization affords sacrificial protection to exposed steel, because of the anodic native of zinc compared to steel, when embedded in concrete, zinc is passivated. Due to scarcity of natural river sand and mining of coarse aggregates, used of the how is to find on alternative without changing the performance of product. All experiments are carried out in reinforced concrete beams incorporated with partial replacement (50%) of coarse aggregate with recycled aggregate and (50%) quarry dust for natural river sand. Comparing it with controlled specimen for ultimate load carrying capacity. In order to provide good waste management practice, we have used construction demolition waste like, existing old building, bridges and foot paths. RCC beams are casted with zinc coated reinforcement along with partially recycled aggregate. The RCC beams are placed in potable water, sewage treatment plant and sea water. Tests are carried out in 28 days, three months, six months and nine months. The main investigated parameter is the ultimate level carrying capacity of beams. All specimens were subjected to a load controlled, two – point bending test until failure. This paper aims to investigate on the use of galvanized reinforcement, recycled aggregates and quarry dust along with recycled aggregate.**

***Index terms-* Hot dip galvanizing, recycled concrete aggregate, quarry dust, beams, bendings, concrete deflection**

1. INTRODUCTION

Reinforced concrete may be defined as a heterogeneous, strong and durable material. Its strength and versatility is achieved by combining the best features of all the used materials. All of geological origin characterized by highly non–linear and ductile stress–strains relationship. Reinforced cement concrete is a composite material incorporated with steel reinforcement, which imparts tensile forces and resistance to cracking. The performance of concrete is based on structural integrity and durability. Resources are limited and day by day, demand is more, hence some other alternative has to find is the need of the hour. The quarry dust and recycled concrete aggregate (RCA) is one of the such alternative has to find is the need of the hour. The quarry dust is one of such alternative can fulfill the properties of natural sand. The use of more that 50% recycle coarse aggregate in concrete, unless carefully managed and controlled is likely to have a negative influence on most of the concrete properties (CCANZ Recycled aggregate in new concrete 2011).

Corrosion of steel reinforcement in concrete structure tends to cracking and spalling of concrete, resulting in costly maintenance and repair an innovative solution to such a problem can be provided by using coated reinforcement as a replacement for plain HYSD bars. Coated reinforcement delays the onset of corrosion and has recently shown a great potential for use in structural applications because of their high strength to weight ratios. Therefore, replacing the plains reinforcement with coated reinforcement delays the potential of corrosion and associated deterioration. Amidst the prominent time–based global research approaches, the coating [epoxy and hot dip galvanizing] technique for reinforcement appears to be a widely accepted practice for reducing corrosion in concrete structure. Over the last 40 to 50 years, a significant body researches has been under taken to investigate the characteristics and behaviour of galvanized steel for its use in RCC. The growing are galvanized reinforcement at this time was just one are of interest in this body of work.

Concrete beams of size 1500 x 200 x 230 mm were reinforced with 4 nos. 16 mm diameter HYSD bar longitudinally and 8 mm stirups at 175 mm c/c with an effective cover of 50 mm shown fig. Than 36 specimens were cast (18 controlled specimen, 18 investigation specimens) incorporated with galvanized rebar, 50% recycled aggregate and 50% quarry dust along with an admixture of naphthalene balls in investigation specimen to maintain W/C ratio. OPC was considered for this research with W/C ratio of 0.55 for M2O grade concrete. Since medium grade mass concrete is mostly used in severe exposure environments. After 24 hours, the specimens were demoulded and subjected to potable water curing for 7 days, then exposed to three different exposures 12 specimens were immersed in potable water, 12 specimens were in marked in sewage treatment plant with a BOD of level of 200–400 gm-3. For different durations of research after 28 days, 3 months, 6 months and 9 months. Specimens were tested as per IS : 516–1964. To find out the results of flexure, normal structural testing procedures were adopted. The experiments were conducted to investigate the ultimate load for both investigation specimen and controlled specimen.

2. LITERATURE REVIEW

Review is presented on a diverse range of laboratory and field–based research that has focused on hot–dip galvanizing, recycled concrete aggregate and quarry dust. Many mile stone papers are extensively referred and they throw light on the history of the origin and development of science and technology of hot dip galvanizing, recycled concrete aggregate and quarry dust, and a chronology of the debate surrounding the use of the product, which at times, has been quite controversial.

Durability of Concrete

The durability of concrete structures are influenced by design environment, exposure conditions, deterioration mechanisms, penetrability of concrete cover layer, cover thickness and the intended life of the structure. Albert Kwan and Henry Wong (2013) stated that the durability of concrete as a construction material and durability of reinforced concrete structures under different environmental conditions are probably the least understood attributes of concrete. No sample theory applies and only incremental advancement based on experiences gained through practice can be achieved. The durability of a structure is its ability to serve its intended purposes for a sufficiently long period of time, (or) at least during its expected service life.

Coated Reinforcement

The application of hot dip galvanizing as a visible means of protecting reinforcement steel concrete structures and also highlighted the technical misconceptions that exist about application and performance provided by the use of hot dip galvanized reinforced steel. The cost of adequate prevention carried and during the stages of design and execution are minimal compared to savings they make possible during the service life and even more. So, compared to the cost of rehabilitation, which might be required later. The main purpose of corrosion protection of reinforcement is to extend the ultimate service life of the structure once the corrosive agents, present in an aggressive environment, have penetrated the concrete cover.

Hot Dip Galvanizing

Zuo Quan Tan (2007) presented a thesis on ‘The effect of galvanized steel corrosion on the integrity of concrete’. The major concern regarding the use of Hot Dip Galvanizing steel as reinforcement in concrete has been the high rate of corrosion experienced by the zinc during the first hours in the fresh, wet and highly alkaline concrete. In the concrete containing 8% cement replacement with silica fume (or) 25% cement replacement with slag, the initial corrosion rates were higher than those in OPC due to higher pH and lower calcium contents of the concrete pore solution. The corrosion behaviour of the zinc coating in alkaline solution is highly dependent on pH, such passivation is only possible at pH less than 13.3. At higher pH, levels the corrosion products are not protective and corrosion continues, rapidly consuming the coating. This process, steel is immersed in a molten zinc bath at temperature of approximately 450oC to 490oC, while immersing, metallurgical reactions occur between the iron and the molten zinc, resulting on the formation of our adherent coating that provides on incredible barrier to corrosive environments and cathotic protection when imperfections exists or in the event of local dissolution of the coating.

Recycled Aggregate

Sellakkannu et al. (2016) made as investigation on 'Study on properties of recycled aggregate' and revealed that, unlike deposits of sand and gravel or stone suitable for crushing into aggregate, which can be anywhere and may require overburden removal and/or blasting, 'deposits' of recyclable aggregate tend to be concentrated near urban area. The application of recycled aggregate has been started in many construction projects. The replacement of natural aggregates by recycled aggregates modifies the concretes compressive strength and elastic modules. In general, concrete produced and recycled aggregates has a lower compressive strength, except concrete made of recycled fine aggregate. The modulus of elasticity model shows that recycled coarse aggregates exert greater influence than recycled fine aggregates. Supply of recycled aggregate depends on physical decay of structures and their demolition. Quality of aggregate play a fundamental role in the quality of concrete. The overall quality of recycled aggregate depends on the attached mortar content. Conventional mix proportionally method was used for recycled aggregate with some adjustments such as using large quantities of cement, without paying attention to the attached mortar content of recycled aggregate.

The concrete made with Recycled Aggregate (RA) showed less durability due to high pore volume, which lead to high permeability and water absorption. High water absorption is due to cement paste adhered on the aggregate surface. However, this can be countered by achieving saturated surface dry (SSD) conditions before mixing. Aggregate absorption can be accurate for during the mix design stage by adjusting the mixing water that will be absorbed by the recycled aggregate. Surface coating was another approach to control absorption and improving properties.

Two Stage Mixing Approach

'Two Stage Mixing Approach (TSMA) for Recycled Concrete Aggregate: TSMAs and TSMAsc' and comparing performance of modified Two–Stage Mixing Approach for Producing Recycled Aggregate Concrete.' They investigated on two mixing approaches by adding silica fume into certain percentage of Recycled Aggregate (RA) in the pre–mix procedure, named as Two Stage Mixing Approach (Silicon Fume)(TSMAs) and adding silica fume and proportional amount of cement into certain percentages of RA in the first mix, named as Two–Stage Mixing Approach (Silica Fume and Cement)(TSMAsc). Their experiments highlighted the improvements resulted for the use of various RA percentages from both TSMAs and TSMAsc. The additions of silica fume and proportional cement content in the pre–mix on TSMAs and TSMAsc can fill up the weave areas on the RA and thus develop a stranger interfacial layer around aggregate and have a higher strength of the concrete.

River Sand and Quarry Dust

The function of the fine aggregate is to assist in producing work ability and uniforming in the mixture. The natural river sand has become scarce and expensive. Hence we are forced to think of alternative materials. The quarry dust (Stone Crusher Dust) may be used to replace the river sand fully or partly. The cost of sand has been sky rocketing, which will be two to three times, costlier than the crusher waste even in places where river sand is a available nearby. In order to product the natural resources such as river sand, quarry dust has been identified, which is a waste product from stone crushing industry and abundantly available almost free of cost, as partial replacement of river sand.

Sakthivel et al. (2013) revealed that result could be found, when the quarry dust is effectively used as a partial replacing material upto 10% of natural river sand in M35 concrete. Reducing the usage of river sand in concrete would, not only cut down the cost of construction, but also reduce the illegal extraction/theft of river sand. In particular, this would also certainly ensure the preservation of natural resources and solve some sustainability issues.

The query dust (stone crusher dust) is replaced with fine aggregate in the objective of utilizing the waste material. The physical and chemical properties of quarry dust satisfy the requirements of fine aggregate. The specific graving is almost the same for both the natural river sand and the quarry dust. The variation of the physical properties like particle size distribution and bulking is a much varying parameter, in which is affects the design of concrete. The work ability very less at the standard water – cement ratio and the water that is required for making the concrete to form in zero slump when a partial replacement required more water. The ideal percentage of replacement of sand with quarry dust is 55% to 70%, when compressive strength is considered. Lakhan Nagpal et al. (2013) made an investigation on 'Evaluation of strength characteristic of concrete using crushed stone dust as fine aggregate', and revealed that the strength of the quarry rock dust concrete is comparatively 10 – 12% more than cost of similar mix of conventional concrete. The water absorption of the quarry dust concrete is marginally higher than conventional concrete.

Exposure of Concrete In Marine Environment

The chloride ion, present in marine breeze and sea water is regarded as the main external agent to damage reinforced concrete in marine environments. It affects the positivity of steel film and provokes the initiation of corrosion. From CSIRO Research Report (1999) it is understood that the disintegration of concrete in marine environment is mostly caused by chemical deterioration such as sulphate attack, magnesium attach and leaching. Physical deterioration from crystallization of soluble hydrated salts in pores or the abrasion promotes for the disintegration of concrete and these attacks on concrete are softening, cracking and partial removal of cover concrete. This in turn exposes a fresh surface for further attack.

Exposure of Concrete In Sewage Environment

Anmar Abdul Wahid Sarray (2013) elaborated that concrete deterioration can be a result of the interaction of several factors that affect the structure of concrete in terms of durability. The most severe exposure conditions for concrete structure is a sewage environment where various kinds of chemical and biological aggressive ions exists. These substances react with concrete through different mechanism and lead to low deterioration of concrete and corrosion of the reinforcement. A complex attack occurs in poorly constructed structures which deteriorate concrete and caused cement paste decomposition, efflorescence formation, spalling of concrete, the occurrence of cracks, and considerable chloride penetration in concrete resulting in the corrosion of the reinforcement.

General Code

ACI manual of concrete (ACI 222R-01) protection of metals in concrete against corrosion gives the guidelines about concrete normally provides reinforcing steel with excellent corrosion protection. The high alkaline environment results in concrete a tightly adhering firm that the steel and protects it from corrosion. IS 383 (1970) specifications for coarse and fine aggregates from natural sources for concrete, IS 10262 (2009) concrete Mix proportioning–guidelines, IS 456 (2000) plain and reinforced concrete, code of practice. As 3600–2009, Australian Standard for concrete structures. IS 9103 and 2645 codes shall be used for concrete admixtures. It is in liquid state with a specific gravity of 1.3 and complying with ASTM C – 494 type E. It accelerates the setting and hardening of the concrete mix thereby achieving high early age strength. Accelerating concrete admixture should be compatible with all type of cement.

3. EXPERIMENTAL PROGRAM

Material Characteristics:

The results demonstrate that the fine aggregate has a lower density than the natural aggregate and recycled aggregate. There is a density difference of 35%

between fine aggregate and natural aggregate of 20 mm and 10% density difference between fine aggregate and recycled aggregate of 14 mm. From the results, the density of recycled aggregate is lower than that of the natural aggregate. The average particle density of natural aggregate is 2900 kg/m3 but that of recycled only 2300 kg/m3. This means the recycled aggregate is lighter than natural aggregate. Particle Density and water absorption of fine and coarse aggregate is tabulated below Table.

Particle Density and water absorption of fine and coarse aggregate

Types and size of aggregate	Particle Density (Dry) Kg/m^3	Particle density (SSD) Kg/m^3	Water Absorption %
20 mm natural aggregate	2886.54	2922.89	1.26
14 mm recycled aggregate	2344.09	2474.57	5.57
Fine aggregate (Sand)	2132.13	2321.32	4.01

The water absorption capacity of recycled aggregate is higher than that of natural aggregate and fine aggregate, the rate of recycled aggregate is around 6% but the water absorption rate of natural aggregate is only 1.4% and fine aggregate is 4% the amount of the recycled aggregate. The recycled aggregate can pass through a sieve of 19 mm, but less than 1% of aggregate only can pass through a sieve of 1.18 mm, almost all the recycled aggregate pass through 13.20 mm, the percentage of particles passing through the sieve is tabulated below Table.

Percentage sieve size passing aggregate

Sieve Size (mm)	Percentage Passing (%)		
	Natural aggregate (20 mm)	Recycled aggregate (14 mm)	Sand
19.00	100.00	100.00	--
13.20	44.48	95.98	--
9.50	8.09	29.41	--
4.75	0.53	0.23	--
2.36	0.37	0.14	98.86
1.18	0.35	--	96.93
60 m	--	--	90.45
300 m	--	--	58.54
150 m	--	--	19.28
75 mm	--	--	4.72
Pan	0.13	0.00	2.80

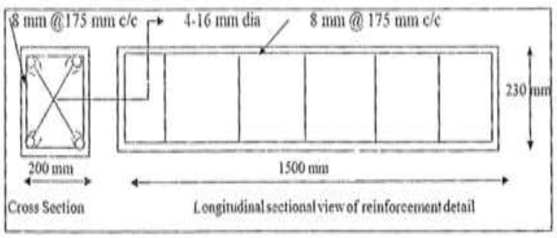
The study began with the collection of materials such as quarry dust, and recycled concrete aggregates, for coating towards, reinforcement. Natural river sand and virgin coarse aggregates are available in local market. The quarry dust is collected from aggregate crusher and filtered by using a sieve of 4.75 mm manually. Then recycled concrete aggregates are collected from dismantled footbridge, cleaned manually to obtain the desired size, since unwanted materials are adhered to it. Cement is the most costly and energy intensive component of concrete. Reinforcements are cut bent and coated with the molten zin of 90 microns after prior cleaning with caustic bath and preheating. Galvanized rebar are then filed to remote the flaws and protruding molten zinc and measured with a gauge to obtain the desired coating thickness as per ASTM 767. Casting of controlled and investigation specimens are carried out as per the standard specifications with a novel technique of TSMA and SSD for recycled aggregates with admixtures for investigation specimen. All the specimens are demoulded and subjected for natural curing, and then the specimens are exposed to different conditions like marine water, sewage treatment plant and potable water. After a period of 28 days, three months and six months, period, the ultimate load carrying capacity of beam is tested.

1 Cement - Type of cement ordinary portland cement (OPC) 43 grade.
2 Fine aggregate - Natural river sand conforming to grading Zone III of table IV of IS : 383 - 1970
3 Coarse aggregate - Crushed (angular), 20 mm maximum size conforming to IS : 383-1970.
4 Quarry dust - Quarry dust conforming to grading zone III of table IV of IS : 383-1970.
5 Recycled coarse aggregate - Recycled crushed (angular) 20 mm maximum size conforming to IS : 383 - 1970.

Concrete beams of size 1500 x 200 x 230 mm were reinforced with

4 Nos. 16 mm diameter HYSD bars longitudinally and 8 mm stirrups at 175 mm c/c with an effective cover of 50 mm shown Fig. Than 72 specimens were cast (36 controlled specimen, 36 investigation specimens; incorporated with galvanized rebar, 50% recycled aggregate and 50% quarry dust along with an admixture of naphthalene balls in investigation specimen to maintain w/c ratio. OPC was considered for this research with w/c ratio of 0.55 for M20 grade concrete, since medium grade

mass concrete is mostly used in severe exposure environments. After 24 hours, the specimens were demoulded and subjected to potable water curing for 7 days, then exposed to three different exposures. 24 specimens were immersed in potable water, 24 specimens were unmarked in sewage treatment plant with a BOD of level of 200 - 400 gm-3. For different durations of research after 28 days, 3 months, and 6 months, specimens were tested as per IS : 516-1964. To find out the results of flexure, normal structural testing procedures were adopted. The experiments were conducted to investigate the ultimate load for both investigation specimen and controlled specimen.



Typical Reinforcement details for the beams

Material Investigations

Ordinary Portland Cement

Ordinary Portland cement was used to produce a control mix mortar in this research. The total requirement was calculated and purchased from local dealers and stored on a dry place in casting yard and kept covered with tarpanlin sheets, to avoid to moisture percolation. DALMIA 43 grade cement was used throughout the investigation. The physical properties of cement obtained from the test conducted as per relevant IS code are shown in Table.

Physical properties of ordinary Portland Cement (43 grade)

S. No	Physical Properties	Tested value	Reference code
1.	Compressive strength 28 days – (Nmm^2)	45.50	IS 4031 (Part 6)
2.	Soundness(Le Chatelier's Method) (mm)	9.0	IS 4031 (Part 3)
3.	Setting Time (Minutes)	Initial-30 Final-500	IS 4031 (Part 5)
4.	Specific Gravity	3.15	Le Chatelier's Flask
5.	Standard Consistency	32%	IS 4031 (part 4)

The raw materials involved in the manufacture of cement consist mainly of lime, silica, alumina and iron oxide. These oxides interact with one another on the kiln at specified temperature to form a complex compound. The relative properties of these constituents are responsible to influence the properties of cement, in addition to the rate of cooling and finess of grinding. The chemical composition of the cement in given Table

Chemical Properties Of Ordinary Portland Cement (43 Grade)

S.No.	Chemical Composition	Average (%)
1.	Insoluble Residues (IR)	3.0
2.	Magnesion Oxide (Mgo)	6.0
3.	Sulphuric Anhydride (So_3)	2.5
4.	Loss of Ignition (Lo7)	5.0
5.	Lime Saturation Factor (LSF)	0.66 - 1.02
6.	Alumina Iron Ratio (A/F)	0.66 - (min)
7.	Chloride (c1-)	0.10

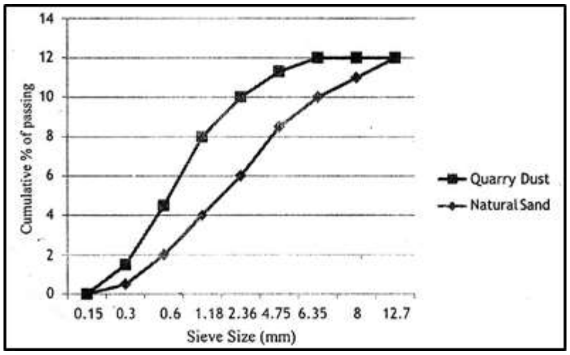
Quarry Dust

Granite fines (or) rock dust shown in fig 5.1 is a by product obtained during of granite rocks and its called quarry dust. Physical and chemical properties are shown in Table and grain size distribution shown in Figure.

Quarry Dust

Physical properties of Quarry Dust

Properties	Quarry Dust	Test Method
Specific gravity	2.60	IS 2386 (Part III) 1963
Bulk Relative Density (Kg/m^3)	1720	IS 2386 (Part III) 1963
Absorption (%)	1.31	IS 2386 (Part III) 1963
Moisture Content (%)	Nil	IS 2386 (Part III) 1963
Fine Particles Less Than 0.075 mm (%)	15	IS 2386 (Part III) 1963
Sieve Analysis	Zone -II	IS 383 - 1970



Grain Size Distribution

Chemical properties of quarry Dust

Constituent	Quarry Rock Dust (%)	Test Method
$Si0^2$	62.5	
$A1_20_3$	18.70	
Fe_20_3	6.51	
C_a0	4.82	
M_g0	2.55	
Na_20	Nil	
K_20	3.20	
$Ti0_2$	1.24	IS:4032-1968
Loss on ignition	0.50	

Recycling is the act of processing the used materials for use in creating new product. Collection of recycled aggregates from dismantled footbridge. The shape of recycled aggregates is rounded and less flattery than natural aggregate's, which is novel techniques of saturated surface dry conditions and two - stage mixing approach are carried out. Properties of natural and recycled aggregate are compared as per IS 383 - 1970 shown in Tables.

Collection of aggregates from demolished structure.

Recycled Aggreagate

Properties of the natural and recycled aggregate

S. No.	Properties	Natural Aggregate	Recycled Aggregate	Max Permissible Limits	Reference Code
1.	Water absorption (%)	1.2	3.5	3	BS 812 - 2
2.	Bulk density (Kg/m_3)	1120	1324.98	1520-1680	IS 383 - 1970, IS 2386 (PI) 1963.
3.	Specific gravity	2.68	2.2	2.70	IS 383 - 1970, IS 2386 (PI) 1963.
4.	Bulk Specific gravity	2.20	2.36	2.60	IS 383 - 1970, IS 2386 (PI) 1963.
5.	Specific gravity (SSD)	2.54	2.40	2.60	IS 383 - 1970, IS 2386 (PI) 1963.
6.	Specific gravity (apparent)	2.60	2.51	2.60	IS 383 - 1970, IS 2386 (PI) 1963.
7.	Aggregate impact value (%)	15.10	31.70	35	IS 383 - 1970, IS 2386 (PI) 1963.
8.	Aggregate crushing value (%)	42.57	28.57	45	IS 383 - 1970, IS 2386 (PI) 1963.
9.	Flakiness index (%)	14.5	19.40	3	IS 2386 (PI) 1963
10.	Elongation index (%)	42	11.30	45	IS 2386 (PI) 1963

Crushing Value

The aggregate crushing value (ACV) is a measure of aggregate resistance to pulverization. The ACV of quarry dust used in this study is in the range of 49.50%, when the land is applied on it. It is understood from previous hypothesis is that; there are no physical relation between the ACV and the compressive strength (Sivakumar et al. 2013).

Soundness Test

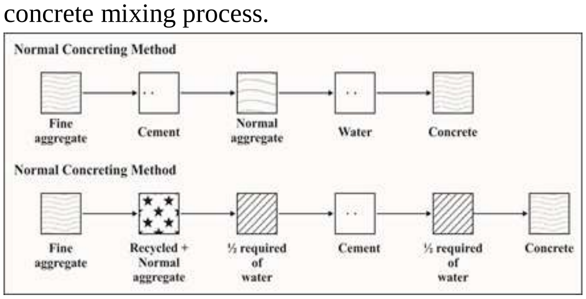
Soundness of aggregate is used to the ability of aggregate to resist excessive in volume as a result of changes in physical conditions. Soundness value in the range of 2.0% to 36.0%, the wide range in the soundness value is due to the size of the quarry dust particles.

Sieve Analysis

A Sieve analysis is a practice or procedure used to assess the particle size distribution of a granular material. The size distribution is often of critical importance to the way the material performs in use.

Two Stage Mixing Approach (Tsma)

Two stage mixing approach was developed to approve the quality of RAC, in which, the mixing process was divided into the two parts and proportionally split the required water into two which was added at different timing. First fine and coarse aggregate were added and mixed for 60 seconds mixed for 30 seconds and next the remaining half of water is added and mixed for 120 seconds. 20% of improvement is achieved during the first stage of mixing. It is half the required water of mixing, leading to the formation of as thin layer of cement slurry on the surface of RA which would permit it in to the process location. At the second stage of mixing, the remaining water is added to complete the concrete mixing process.



Comparison of normal mixing and two stage mixing approach for controlled and investigation specimen

Comparison of Natural Aggregate and Recycled Coarse Aggregate

	Diameter	Relative density (over dried)	Relative Density	Water Absorption
NA	5.20mm	2.70	2.80	2.80
RCA	5-20mm	2.45	2.50	3.50

Hot - Dip - Galvanizing (Hdg)

It is the process of coating iron and steel with a layer of zinc immersing the metal in a basis of molten zinc out at a temperature of around 840□F (449□C).

Properties of hot - dip galvanized bars and MS bar.

S. No	Properties	MDG	Mild steel
1.	Metallurgical bond	3600 pounds/sq.inch	
2.	Young's modules of elasticity	200 x 10^3Mpa	210 x 10^3 Mpa
3.	Density	7.87g/cm^3	7.85 g/cm^3
4.	Coefficient of thermal expansion	12.4μm/m/^{0}c in 20^0c to 100^0c range	7.3 (10-6 in / in ^{0}F)
5.	Thermal conductivity	Low - carbon/HSL AS : 89 w/m^{0}c at 20^0c	
6.	Specific heat	481/J/kg/^{0}c in 50^0c to 100^0c range	490J/kg/^{0}c in 50^0c to 100^0c range
7.	Electrical resistivity	0.142μΩ^{0}m at 20^0c	

When exposed to the atmosphere the pure zinc (Zn) results with oxygen (02) to form zin oxide (Zno), which further results with carbon dioxide (C02) to form zinc carbonate (ZnCo3), usually dull grey, fairly strong material, that protects the steel underneath from further corrosion in many circumstances. Galvanized steel is widely used in applications where crystallization resistance is needed and can be identified by the crystallization pattering on the surface. Properties of HDG and MS are shown in table.

Physical properties of Hot - dip Galvanized coating (referred from American galvanizer association)

Metallurgical Bond

Hot - dip galvanizing is a factory - applied coating that provided a combination of properties unmatched by other coating systems because of its unique metallurgical bond with steel.

Impact and Abrasion Resistance

The ductile outer zinc layer provides good impact resistance to the bonded galvanized coating. The hardness of the zeta, gamma, and delta layers is actually greater than that of the base steel and provides exceptional resistance to coating damage from abrasion.

Corner and edge Protection

Corrosion often begins at the corners or edges of products that have not been galvanized. Epoxy coatings, regardless of application method, are the thinnest at such places. The galvanized coating will be at least as thick, possibly thicker on edges and corners as on the general surface. This provides equal or extra protection to these critical areas.

Mechanical Properties of Hot - Dip Galvanized coatings
(Referred from American galvanizer association)

Ductility and Yield/Tensile Strength
Ductility and strength of reinforcing steel are important to prevent brittle failure of reinforced concrete. It is demonstrated conclusively that, with correct choice of steel and galvanizing procedures, there is no reduction in the steel's ductility.

Water
Available potable water was used for mixing and curing of concrete. The amounts of solids were below the permissible limits as specified by IS : 456 - 2000. The result of quality control tests done on water is presented in Table 4.90 PH value is 6.5 to 8.5 as per Table I of IS 10500 - 2012 for construction of building.

Results of Water Quality Analysis

S. No	Description of Test	Water Sample	Max permis-sible Limits
1.	P^H value	7.5	6.0 – 9.0
2.	Hardness (ppm)	400	1000
3.	Sulphate (ppm)	105	400
4.	Chlorides (ppm)	130	500

Location of Water Sample
Water samples were collected from Thiruvottiyur (Kasimedu) harbor point (marine environment), from STP plant at Kodungaviyur (sewage treatment plant) and potable water (stored in a Ground level water tank) was collected from Red Hills, Chennai, Locations of water samples are shown in Table 4.10. Representative sample of water shall be drawn as presented in IS 1622 and IS 3025.

Location of water Sample

Location	Latitude	Longitude
Thiruvottiyur (Kasimedu harbor point (exposed to sea water)	13.1542595	80.3056635
Red Hills (exposed to potable water)	13.1859925	80.1900066
Kodungaiyur (exposed to STP plant)	13.1426761	80.2614627

Alkalinity Test
Alkalinity is the quantitative capacity of an aqueous calculation to neutralize an acid. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or waste water. It is one of the test measures of the sensitivity of the stream to acid inputs. These can be long - term changes in the alkalinity of streams and rivers in response to human disturbances.

Chloride Test
The chloride is the anion (negatively charged ion) Cl- It is formed, when the element chloride (a halogen) gains an electron or when a compound such as hydrogen chloride is dissolved in water or other polar solvents. Chloride salts such as sodium chloride are often very soluble in water.

Turbidity test
Turbidity is the cloudiness or hazincss of a fluid caused by large numbers of individual particles that are generally invisible to the ranked, similar to smoke in air. The measurement of turbidity is a key test of water quality.

Concrete
Concrete is a heterogeneous material (composed of fine and coarse aggregates) characterized by nonlinear and ductile stress strain relationship. The nonlinear behavior is attributed to the formation and graded growth of micro cracks under loading. The micro cracks can be galvanized as bond cracks and natural cracks.

Workability
That workability is a very important property of concrete, which will affect the rate of placement and to degree of compaction of concrete. Slump test is carried out as per IS 1199-1959.

Consistency
The degree of consistency is depended on the nature of works and type of compaction. Consistency of cement paste is carried out as per IS 4031-4.

Water / Cement ratio
Water Cement ratio (IS 10262-2009) is the ratio of water in a mix to the weight of cement. The quality

of water that required for a mix is dispending on the mix proportions, types and grading of aggregates.

Grading of Aggregates
The smooth and rounded aggregate will produce a more workable concrete than the sharp angular aggregate (IS 383-1970).

Cement Content
The greater workability can be obtained with the higher cement content.

Slump Test
The test measures consistency of concrete in that specific batch. It is performed to check the consistency (also known as workability or fluidity) of freshly made concrete and therefore the ease with which concrete flows. Workability test are carried out as per IS 2386 p II-1963, Cl. 4.2. 3.

Two stage Mixing Approach
The two stage mixing approach (TSMA) for investigation specimen was developed for improving the quality for the recycled aggregate concrete, in which a kind of methodology was applied and the mixing process was carried out in two stages by proportionally splitting the required water into two parts, which is added at different timings.

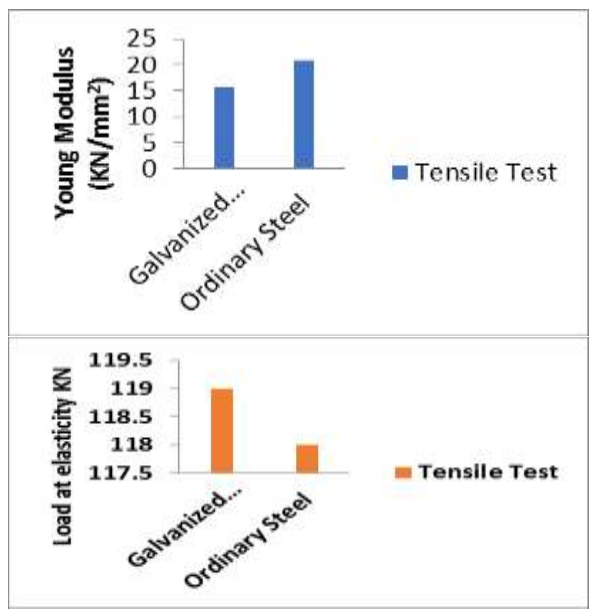
4. RESULT AND DISCUSSIONS

In this study an overview about the incorporation of solid waste (Aggregates from dismantled concrete and waste from stone crushing into useful material by recycling) is provided. Quarry dust improves the strength properties of concrete which is on par with that of conventional concrete. Workability is our main concern and it will be managed by using admixtures or superplasticizer. Recycling concrete reduces natural resources exploitation and transportation costs, besides decreasing the waste gain to land fill. However, it has a little impact on reducing greenhouse gas emissions.
Further testing and studies on recycled aggregate concrete are highly recommended to specify the strength characteristics of recycled aggregates for application on high strength concrete. Partial incorporation of the quarry dust in concrete is desirable because of its benefits, such as useful disposal of by products, reduction of river sand consumption as well as durability and longevity of the structure.

Tensile Test
Tensile test is carried as per clause 3.100g is 178-2008, negligible elongation difference is noted in HDG, when compared with us HYSD bars.

Tensile test for Reinforcement

Material	Original Length (mm)	Change in length (mm)	Extension (mm)	Strain	Load at elastic limit (kn)	Stress kn/mm^2	Young's modulus (E) kn/mm^2
Galvanized Reinforcem -ent	1000	1038	38	0.038	119	0.593	15.60
Ordinary Reinforcem -ent	1000	1028	28	0.028	118	0.587	20.97



Tensile test for reinforcement

Tests for Concerete
Water cement ratio falls under 0.4 to 0.6 as per IS code 10262 (2009) for nominal mix. Workability of concrete cl.7(2.3) of IS 456-2000 and IS 456-1978 specified workability in terms of compacting factor

Vee-bee time and slump. As per new revision workability is mentioned in terms of slump.

Results for water cement ration, workability and slump

	Water cement ratio	Workability	Slum
Concrete (approximately)	0.55	0.90 CF (IS 1199-1959)	60mm

Ultimate Load and Crack Behavior of Reinforced Concrete under Flexure

All beams were tested under two point loading by using universal testing machine of 500 KN capacities. All the beams were failed in flexural failure, the first crack were appeared in flexural span in vertical direction of the that diagonal cracks are developed. In control beams, first hour crack were initiated at bottom sides in the mid span of the beam and shows propagation towards upward direction at a load of about 9.26 ton. The first crack was seen in flexural span at 80mm to 100mm from centre of the beam towards point load. As the loud increases additional flexural cracks and shear cracks were developed. Finally beam failed by conventional ductile failure with yielding of the steel followed by crushing of concrete on compressive zone.

Ultimate Load For 28 Days

When considering the duration of 28 days, load at initial and final concrete are similar, invisible difference is observed. In case of controlled specimen, crack formation developed across the beam depth vertically with an initiation of hair line cracks. Whereas diagonal cracks are developed in case of investigation specimen.

Ultimate Load Carrying Capacity for 28 days

Specimen Identification	SO1	SO2	SO3	SS1	SS2	SS3	SW1	SW2	SW3
Load at initial crack (ton)	9.30	8.15	10.35	10.15	12.60	11.15	12.10	12.05	11.90
Load at ultimate crack (ton)	19.35	18.55	19.65	18.75	20.35	20.20	21.25	19.50	21.05
Specimen Identification	RO1	RO2	RO3	RS1	RS2	RS3	RW1	RW2	RW3
Load at initial crack (ton)	10.10	8.50	9.35	9.30	9.50	9.70	10.50	13.50	12.50
Load at ultimate crack (ton)	19.50	17.90	20.10	18.25	19.75	19.24	20.05	21.00	19.45

In all the specimens, stiffness of the beams between the initial and final cracks is more or less identical. Load deflection curve shows linear elastic behavior up to yielding of steel at a load of 19.35, 18.55 and 19.65 tons respectively for the controlled specimen immersed in potable water. Similarly for controlled specimen immersed in sea water, yielding occurs at 18.75, 20.35 and 20.20 respectively and for controlled specimen immersed in sewage water is 21.25, 19.50 and 21.05 respectively as per table 6.7. In case of investigation specimen collapse of entire beam is observed during yielding. Load at initial crack for investigation specimen is similar to controlled specimen. It is observed from many previous findings, investigation specimen is gaining strength after 3 months, and hence the collapse of investigation specimen is as expected. Failure of both the specimens is only due to flexure and not by shear (Since the formation of crack and deflection initiated from the middle of the specimen).

Ultimate Load for 3 months

Ultimate Load Carrying Capacity for 3 months

Specimen Identification	SO1	SO2	SO3	SS1	SS2	SS3	SW1	SW2	SW3
Load at initial crack (ton)	9.55	9.70	10.40	10.15	11.35	12.95	12.50	11.95	13.50
Load at ultimate crack (ton)	19.90	18.05	18.45	18.50	20.50	18.90	23.35	22.00	22.92
Specimen Identification	RO1	RO2	RO3	RS1	RS2	RS3	RW1	RW2	RW3
Load at initial crack (ton)	10.05	9.95	10.25	9.50	8.70	9.15	11.75	11.65	12.75
Load at ultimate crack (ton)	16.75	16.55	16.90	19.50	18.50	19.65	17.50	18.50	21.00

At the stage of the 3 months, the load at initial crack is identical for both controlled and investigation specimen, whereas ultimate load for controlled specimen immerse in potable water is little higher than investigation specimen. Ultimate load for beams immersed in sea water, both controlled and investigation specimen is similar. In case of beams immersed in sewage water, ultimate load for investigation specimen is lesser than the controlled specimen. No shear cracks were observed in both the specimens. it was noted that collapse of the investigation specimen is sudden. Hair line cracks were initially seen before it develops more width of cracks. Stiffness of both the specimens is enhanced, when 28 days stiffness is compared.

Ultimate Load for 6 Months

At the stage of 6 months, when the beams immersed in potable water, initial and ultimate loads are more identical and negligible difference were seen in controlled and investigation specimen. In all the cases, specimens are failed in flexure, after yielding of the longitudinal steel bars.

Ultimate Load Carrying Capacity for 6 months

Specimen Identification	SO1	SO2	SO3	SS1	SS2	SS3	SW1	SW2	SW3
Load at initial crack (ton)	10.55	10.55	11.50	14.05	13.10	12.55	15.35	15.65	14.50
Load at ultimate crack (ton)	22.35	19.55	21.75	17.95	17.95	19.20	22.95	19.10	19.40
Specimen Identification	RO1	RO2	RO3	RS1	RS2	RS3	RW1	RW2	RW3
Load at initial crack (ton)	10.10	10.25	10.65	13.00	15.50	12.50	14.40	13.50	13.70
Load at ultimate crack (ton)	17.90	19.95	19.05	17.25	18.20	21.25	20.25	19.15	21.00

The first flexural cracking was observed at the mid-span of the specimens at approximately 50% of the ultimate flexural strength. Subsequently, the flexural cracking spread widely towards the supports of the beams. When them reinforcement yielded, the flexural cracks widened severally in all beams.

When the beams immersed in sea water, load at initial crack is more than 60% of the ultimate load. It shows that the stiffness of investigation specimen increased on age of concrete (or) it was gaining strength after 6 months. Ultimate load for controlled and investigation specimens are identical and negligible difference are seen; collapse and propagation of cracks are similar during failure.

Ultimate Load one for Nine Months

Ultimate Load Carrying Capacity for Nine Months

Specimen Identification	SO1	SO2	SO3	SS1	SS2	SS3	SW1	SW2	SW3
Load at initial crack (ton)	11.15	11.20	1210	15.25	14.55	14.95	16.20	15.90	17.05
Load at ultimate crack (ton)	23.90	21.82	21.25	22.60	24.00	22.50	22.70	21.90	23.05
Specimen Identification	RO1	RO2	RO3	RS1	RS2	RS3	RW1	RW2	RW3
Load at initial crack (ton)	10.35	11.05	10.55	14.65	14.90	13.55	13.20	14.05	14.25
Load at ultimate crack (ton)	19.05	18.45	22.90	22.50	20.50	22.95	22.85	2.80	22.50

Ultimate load for investigation specimen is less than compared with controlled specimen and from the results, it is clear that recycled concrete aggregate and the quarry dust did not significantly affect the ultimate flexural behavior. Significant signs of corrosion seen in controlled specimen, whereas no films of corrosion were found in investigation specimen. Concrete cover distorted, and the bottom steel bars and completely exposed. Concrete strain in the compression zone increased up to the ultimate compressive strain, which resulted in concrete crushing at the top of beams and finally flexural towards the supports of the beams.

Small amount of rust adhered to the dismantled portion after collapses were seen in controlled specimen. Galvanized coatings were not disturbed even after one year period in the investigation specimen, when it was immersed in the severe exposures of the sewage and marine. It is considered that these observations potentially have serious implications for the assessment of the ultimate load carrying capacity of beams exposed to various environments. Anticipated loads at initial and final cracks are reached for both controlled and investigation specimen.

Ultimate Load Carrying Capacity (mean values of 3 specimens)

Specimen Identification	SO1	SO2	SO3	SS1	SS2	SS3	SW1	SW2	SW3
Load at initial crack (ton)	11.15	11.20	1210	15.25	14.55	14.95	16.20	15.90	17.05
Load at ultimate crack (ton)	23.90	21.82	21.25	22.60	24.00	22.50	22.70	21.90	23.05
Specimen Identification	RO1	RO2	RO3	RS1	RS2	RS3	RW1	RW2	RW3
Load at initial crack (ton)	10.35	11.05	10.55	14.65	14.90	13.55	13.20	14.05	14.25
Load at ultimate crack (ton)	19.05	18.45	22.90	22.50	20.50	22.95	22.85	2.80	22.50

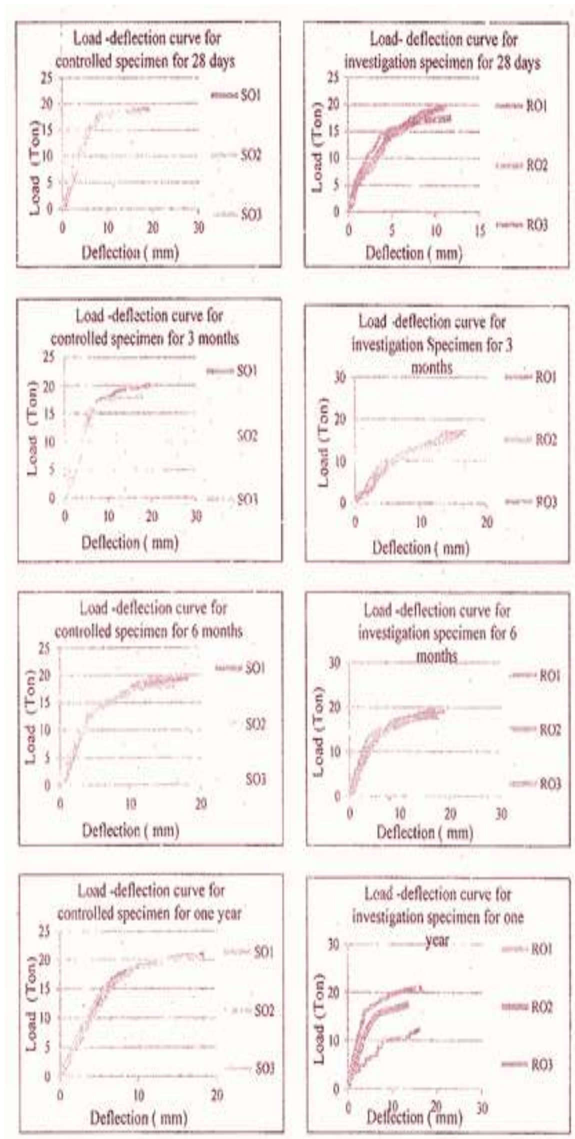
Load at an initial crack for investigation specimen is less, than compared with the controlled specimen up to a period of 6 months, and gaining strength takes a lead from 6 months to nine month period. It can be seen that investigation specimen is gaining strength after the duration of six months and maintains the inflation up to nine month period. Investigation specimens immersed in sewage and sea water will resist up to a mean load of (SS) 23.05 t and (RS) 23.72 t respectively, when compared with controlled specimen with a mean load of (SW) 22.5t and (RW) 23.05. Ultimate load significantly rises in the investigation specimen. In the case of beam immersed in potable water for nine month, the ultimate mean load for investigation specimen (RO) (20.13t) was comparatively less, when compared with the controlled specimen (SO) (22.3t).

Control beams were failed in flexure at a load 19.17 ton. Table 6.11 summarized maximum load experienced by the all type controlled and investigation specimen. Load at initial crack ultimate load for 28 days beams immersed in sewage plant is more. When compared to others for both controlled and investigation specimen. Mean ultimate load is more or less similar for controlled and investigation specimen. Diagonal cracks are developed in investigation specimen.

Load - Deflection

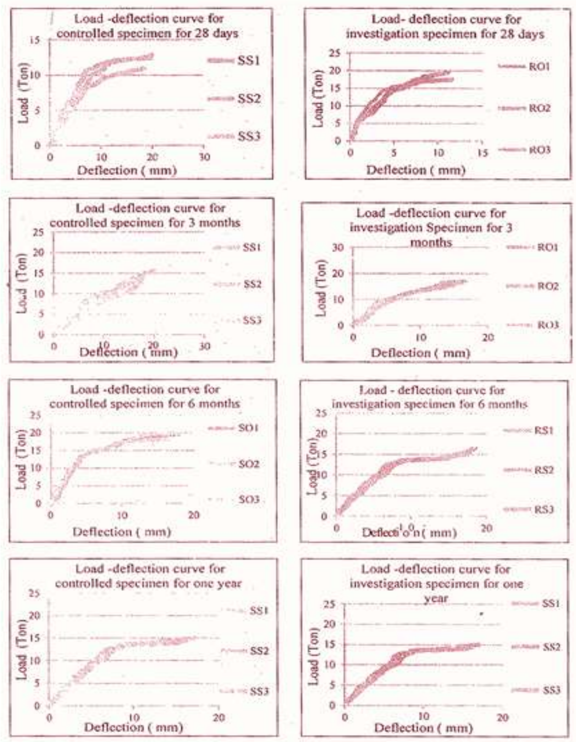
A graph in which increasing flexural loads on a beam are plotted along the vertical axis and deflections resulting from these loads are plotted along the horizontal axis. The load deflection plots obtained during each load tests are shown in Figure 6.6, 6.7 and 6.8.

Load - Deflection curve the Beams immersed in Potable Water



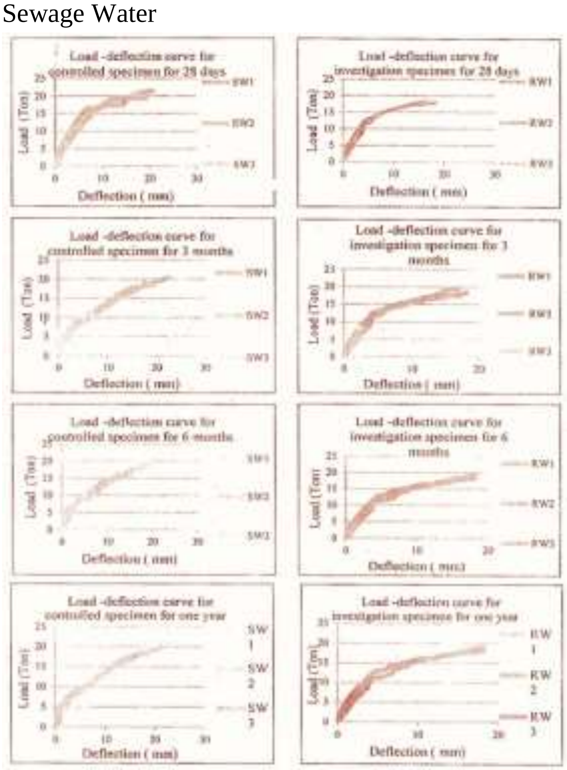
Load-deflection curve for the beams immersed in potable water

Load - deflection curve for the beams immersed sea water



Load-deflection curve for the beams immersed sea water

Load - deflection curve the Beams immersed in Sewage Water

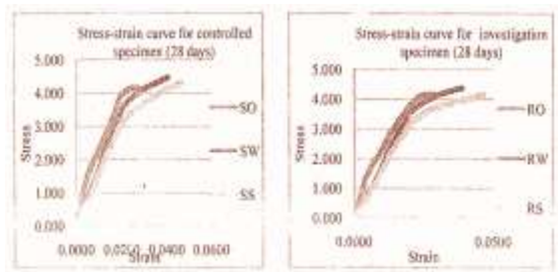


Load-deflection curve for the beams immersed in sewage water

Stress-Strain Curve

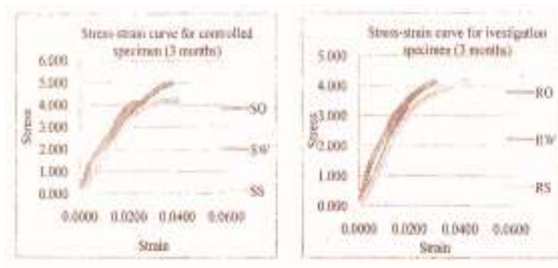
Stress-strain curve is a chart or curve showing the relation between the load or stress on a structural member or specimen of material and the corresponding strain or deformation.

Stress-strain Curve for 28 days



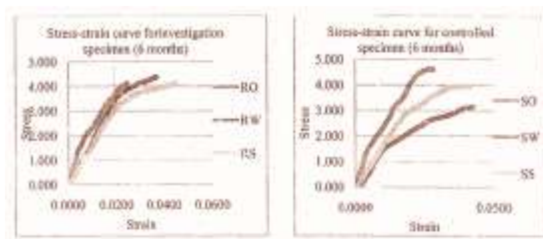
Stress-strain curve for 28 days

Stress-Strain Curve for 3 months



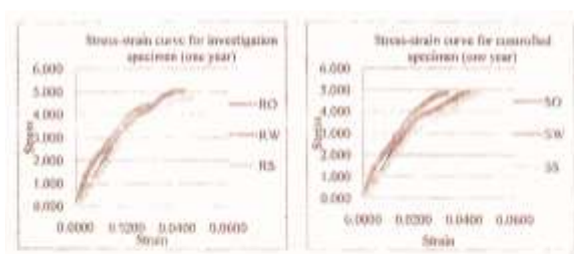
Stress-strain curves for 3 months

Stress-Strain Curve for 6 months



Stress-Strain curves for 6 months

Stress-Strain Curve for 9 months



Stress-Strain curves for nine month

It is learnt that there is progressive increase in the stiffness of the investigation specimen from the stage of initial crack till the ultimate stage in all periods. From the above testing results, it is known that the quarry dust may be used as an effective replacement material partially for natural river sand. 28 days compressive strength of 100% replacement is 11.8% higher than that of the controlled specimen. It is a hypothesis that the longevity of the structure will be for more than 100 Years without any major retrofitting and periodical maintenance of the structure. Additional productive means should always be required. If there is any risk for early age chloride exposure during concrete before it has gained sufficient maturity and density, special precautions or protective measures also should be required. Service life of the structure is a stochastic hectic quantity, which is interposed with Duracrete, which is a design method for durability of concrete structure specifically mentioned about the severe environments.

It was an interesting fact that, when beams are immersed in STP, the maximum load carrying capacity is less for in controlled specimen, when it is compared with investigation specimen. Investigation specimens immersed in potable water exhibited diagonal cracks, whereas controlled specimen developed vertical cracks. Field exposure tests are naturally time consuming and can also be expensive, if the aim is to follow the time dependent changes in the concrete microstructure with respect to all relevant properties. Therefore it is important to establish a common approach for field monitoring of concrete to make it possible to compare and evaluate experiences from different exposure sites. However, such a program should not limit the freedom of research to certain methods. Densification of concrete during the first year of exposure hides the genuine reaction. It will pluck the plastering surface along with the corroded portion of reinforcement after some years, thereby deterioration will be faster.

It was demonstrated that during zinc corrosion in ordinary Portland cement (OPC) concrete, calcium hydroxyzincate forms on untreated HDG steel which provides sufficient protection against corrosion. Therefore, it is obvious that treating HDG rebar with dilute chromic acid is worthless method of passivating zinc. In concrete structure, the pore solution is highly alkaline due to the presence of calcium, sodium and potassium hydroxides. Immediately after mixing, the pore solution is saturated with calcium hydroxide and it contains a small amount of sodium and potassium hydroxide giving a pH of at least 12.6. The pH value increases to above 13 within the first several hours and to a maximum of approximately 13.7 as hydration continuous. The same is also true, when pH decreases to a level below 6. Galvanized rebar shows higher bond strength than the cleaned non-galvanized rebar. Coating influences the bond strength to a limited extent. Mechanism of chromating is an issue that remains controversial for the researchers till now even though as per ASTM requirements, galvanized steel have to be quenched in a solution containing a minimum of 0.2% wt of sodium dichromate solution or aluminum of 0.2% chromic acid solution. Even the galvanizing industry generally believes that chromating is necessary to prolong the life of the zinc coating and maintain the integrity of reinforced concrete. Ft is generally observed that it is far more difficult to remove galvanized bars from concrete, compared to either black or epoxy coated bars because of the tight adhesion of the matrix to the zinc alloy surface of the bar. In this context, further research is still required to establish deflection and cracking behaviour of beams in flexure within the serviceability load range when using galvanized bars, whether chromate is treated or not.

Galvanized reinforcement can tolerate chloride levels in concrete at least 2.5 times higher than those causing corrosion of black steel under equivalent concrete and exposure condition. Results indicate that the total period over which galvanizing delays the onset of corrosion of reinforcing steel in concrete is of the order of 4-5 times that for the corrosion of black steel in equivalent concrete and exposure conditions. Incorporation of HDG, recycled aggregates and the quarry dust seems to be compatible with existing conservative concreting procedures. A film of corrosion is not prolific after one-year period. It is benign to implement hot dip galvanizing, and the use of quarry dust and recycled concrete aggregate. One of the most effective and inexpensive methods of protecting steel sheet in near neutral aqueous environment is to coat it with a thin layer of zinc, either by hot dipping i.e., galvanizing or more usually by electro deposition. In near neutral aqueous media, the zinc coating resists corrosion by forming a passive surface of ZnOH2. At defects in the coating caused by abrasion and at cut edges, the exposed iron is cathodically protected by corrosion of the newly exposed zinc, producing Zn (OH)2, which covers the exposed iron stifling further attack.

Zero maintenance has always been the most intelligent percentage in RCC structures. It is learnt that there is a progressive increase in the stiffness of the investigation specimen when compared with controlled specimen from the stage of first cracking of concrete until the ultimate stage. Load carrying capacity of beams incorporated with HDG quarry dust and recycled aggregates are higher than that of the controlled specimen.

5. CONCLUSIONS

From the detailed experimental results and analysis the following conclusions are drawn.

1 Uses of Galvanized rebar, recycled aggregates and the quarry dust are unavoidable in near future. Rivers should be declared as national property. Mining of sand in large quantities jeopardizes the regional economy, since the extracted material is not renewed.

2 Investment for galvanization can be equalized by partial replacement of aggregates with inflated durability and serviceability of the structure by delaying the onset of corrosion.

3 There is severally little (or) no evidence of red rust corrosion on the bars and only superficial corrosion of the zinc creating with perhaps 0.1% loss of coating thickness.

4 Future research and development works shall consider user–friendly mechanism for recycling the concrete aggregated, and experiment on how to minimize the cost of galvanizing by enhancing the volume of work.

5 To improve the properties of the quarry dust by adding suitable admixtures for workability and to maintain the water cement ratio, the incorporation of recycled aggregate TSMA and SSD suitably carried out.

6 The substitution of the quarry dust and recycled aggregate will serve as both solid waste management and waste recovery.

7 This research has reached a very important finding that the incorporation of coated reinforcement with 50% replacement of both the river sand and raw aggregate by using the quarry dust and the recycled aggregate will yield positive results.

8 The ultimate level carrying capacity of beams gets strengthened and the corrosion effect gets reduced, apart from other consideration of propagation of cracks, strains and permeability.

9 By knowing the ultimate load, the expected load during the life time of the structure, an adequate margin of safety is assessed. It has come to know of the structure is no longer proportional to strain.

10 The cost incurred for recycling is lower than the cost invested for landfill, then this process can be carried out economically and commercially. Slight amount of premium costs may be acceptable since recycling may earn good a social image.

11 The usage of building demolished waste is very important because, demolished waste is gradually increasing with the increase in population and increasing urban development. Investigation and analysis trade on recycled aggregate is because, it is easy to obtain and the cost is cheaper than natural aggregate. Natural aggregates used to extract but recycled aggregate can ignore this process.

REFERENCES

[1] ACI 211.1-91, Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete, Reported by ACI Committee 211.

[2] ACI 288.2R, Non-destructive Test methods for Evaluation of concrete in Structures, Reported by ACI Committee 228.

[3] ACI Manual of concrete (ACI 222R-01) Protection of Metals in Concrete against Corrosion.

[4] Anitha Selva Sofia, SD, Gayathri, R.Swathi, G and Prince Arulraj, G 2013, 'Experimental Investigation on Quarry Dust Concrete with Chemical Admixture', International Journal of Latest Research in Science and Technology, voo.2, no.2, pp.91-94.

[5] Anmar Abdul Wahid Sarray 2013, 'The Deterioration of Concrete in Wastewater Treatment Plants', Partial Fulfillment of the Requirements for the Degree of Master Science, Eastern Mediterranean University.

[6] Anzar Hamid Mir 2015, 'Replacement of Natural Sand with Efficient Alternatives: Recent Advances in concrete Technology', Journal of

Engineering Research and Applications, vol.5, pp. 51-58.

[7] ASTM (A767/A 767 M-05 Standard Specification for Zinc Coated (Galvanized) Steel Bars for Concrete Reinforcement.

[8] ASTM C 1152, Standard Test method for Acid-Soluble Chloride in Mortar and Concrete.

[9] Balamurugan, G and Perumal, 2013, 'Behaviour of concrete of the use of quarry dust of replace sand–An Experimental Study', International Journal of Engineering Science and Technology', vol.3, no.6, pp.776-781.

[10] Bhanupravalika, S and Lakshmi, V 2014, 'A study of Fly Ash Concrete in Marine Environment', International Journal of Innovative Research in Science Engineering and Technology, vol.3, no.5, pp.12395-12401.

[11] ChandanaSukesh, KatakamBala Krishna, Sri LakhsmiSaiTeja, P and KanakanbaraRao, S 2013, 'Partial Replacement of Sand with Quarry Dust in Concrete', International Journal of Innovative Technology and Exploring Engineering, vol.2, no.6, pp.254-258.

12 Devi, M and Kannan, K 2011, 'Enhancement of corrosion resistive properties of concrete containing quarry dust as fine aggregate using inhibitor, the International Conference on Science and Engineering, Vaish Technical Institute, Hariyana, pp. 325-331.

13 Illangovan, R, Mahendran and Nagamani, K 2008, 'Strength and Durability Properties of Concrete Containing Quarry Rock Dust as Fine Aggregate', ARPN Journal of Engineering and Applied Sciences, vol.3, no.5, pp.5-7.

14 IS 383-1970-2002, Specification for coarse and fine Aggregates from Natural Sources for Concrete, Bureau of Indian Standards, New Delhi, India.

15 IS 456 2000, Plain and Reinforced concrete, Bureau of Indian Standards, New Delhi, India.

16 IS 8112–1989. Specifications for 43 grade Ordinary Portland Cement, Bureau of Indian Standards.

17 Lakhan Nagpal, Arvind Dewangan, Sandeep Dhiman and Sumit Kumar 2013, 'Evaluation of Strength Characteristics of Concrete using crushed stone dust a fine aggregate', International Journal of Innovative Technology and Exploring Engineering, vol.2, no.6, pp.102-104.

18 Parande, AK, Ramaswamy, PL, Ethirajan, S Rao, CRK and Palanisamy, N 2005, 'Deterioration of reinforced concrete in sewer environments', Research gate, vol.159, no.1, pp.11-20.

19 Ruiz, J and Chunga, K 2015, 'Determination of the Efficiency of Cathodic Protection Applied to Alternative Concrete Subjected to Carbonation and Chloride Attach', International journal of electrochemical science, vol.10, pp.7073-7082.

20 Sakthivel, PB, Ramya, C and Raja, M 2013, 'An Innovative Method of Replacing River and by Quarry Dust Waste in Concrete for Sustainability', vol.4, no.5, pp.246-249.

21 Sellakkannu, N and Subramani, V 2016, 'Study on Properties of Recycled Aggregate–A Review', Imperial Journal of Interdisciplinary Research, vol.2, no.3, pp.496-475.

22 Sivakumar, A and Prakash, M 2011, 'Characteristics Studies on the Mechanical Properties of Quarry Dust Addition in Conventional Concrete', Journal of Civil Engineering and Construction Technology, vol.2, no.10, pp.218-235.

23 Sivakumar, N and Manikandan R, 2013, 'Experimental Investigation on Flexural Behavior of High Strength Concrete Beam', International Journal of Science and Research, vol.2, pp.73-78.

24 Sudhir, S, Kapgate, SR and Satone 2013, 'Effect of Quarry Dust as Partial Replacement of Sand in Concrete', Indian Streams Research Journal, vol.3, no.5, pp.1-8.

25 Yan Li 2001, 'Corrision Behavior of Hot Dip Zinc and Zinc Aluminium coatings on Steel in Seawater'. The Journal of Bull Mater Science, vol.24, no.4, pp.355-360.

26 Yeoman, SR 1991, 'Comparative Studies of Galvanized and Epoxy Coated Steel Reinforcement in Concrete', Research Report No.4 103, Synopsis. The University of new South Wales, Australia.

27 ZuoQuan Tan 2007, 'The Effect of Galvanized Steel Corrosion on the Integrity of Concrete' Ph.D. Thesis, University of Waterloo.