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A STUDY ON STRESS-STRAIN BEHAVIOUR OF TIE CONFINED CONCRETE CONTAINING CERAMIC TILE WASTE AND WASTETYRE RUBBER AS PARTIAL REPLACEMENT TO BOTH COARSE AND FINE AGGREGATES

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Abstract *Concrete is a composite material composed of 65-70% of its volume with natural resources such as sand and crushed stones. Concrete industry is one of the major consumers of these natural resources. For sustainable development, these natural resources used in concrete should be replaced by alternative materials such as waste tyre rubber, ceramic tiles waste etc. Worldwide production of waste tyre is growing up due to rapid increase in the use of tyres in automobile industry. The disposal of waste tyres has become major problem even in India and most of the waste tyre rubber is used as a fuel in brick kilns and cement kilns. Unfortunately, this kind of usage is not environment friendly and hence the use of waste rubber in concrete has been thought as an alternative disposal method which is environment friendly. Similarly in recent constructions, the consumption of ceramic materials such as tiles is increasing day by day and a large quantity of the same is converting into wastage during processing, transporting and fixing due to its brittle nature. The use of this ceramic tile waste as aggregates in concrete can reduce the negative environmental effects and exhaustion of the natural resources. Hence, in this work both conventional coarse and fine aggregates are replaced by ceramic tile waste & waste tyre rubber in the proportions that yield optimum strength. Further, Concrete is known to be brittle material which has much lower strength in tension than in compression and the behavior of concrete can greatly be ameliorated by confining it with ties in order to achieve a ductile concrete. In this experimental study, the effects of confinement on the stress-strain behaviour of 100mm × 100mm × 200mm prisms of standard & high strength concrete (M40 & M70 grades) are investigated under the axial compression. Waste tyre rubber has been used as a replacement to both coarse aggregate and fine aggregate in proportion of 4% by weight in both grades of concrete mixes. In the same way, waste ceramic tile is used asa replacement to both coarse aggregate and fine aggregate with 4 percentage of replacement by weight in standard & high strength concrete mixes .The lateral ties of 6mm diameter mild steel and 8mm diameter HYSD steel bars were used for confinement in both grades of concrete. The test specimens were provided with ties at different spacings. The test prisms of specimens were cast with 0, 2, 3, 4, and 5 number of ties. Tests were conducted to determine fresh & hardened state properties such as slump, compressive strength, stress-strain behavior & confinement studies of prisms. A total of 162 prism specimens of size 100 mm × 100 mm × 200 mm (81 no's for M40 concrete & 81 no's for M70 concrete) and 18 companion cube specimens of 100 × 100 ×100 mm size were caste and tested. Tests were conducted after 28 days of conventional water curing. Compressive strength was determined using companioncubes while stress-strain behavior was determined using test prisms and from obtained results ductility factor, strain ratio and stress ratios were calculated.*

Key Words: Confinement index, Waste tyre, Ceramic waste tile, Confinement, Compressive strength, Stress-strain behaviuor, Ductility factor, Stress ratio, Strain ratio.

1.INTRODUCTION

Concrete exhibits a brittle failure under compression, which leads to a rapid loss of load carrying capacity. The confinement reinforcement is used to restrain the concrete from expansion and thus prolongates the failure. In recent years, high strength concrete has been widely used in buildings, bridges and other structures. The use of high strength concrete in columns can significantly reduce the size of the column andconsequently reduce the dead load on the foundation. It is an accepted fact that the strength and ductility of reinforced concrete column can be improved by confining it insteel binders, as ties in compression members and as stirrups in beams. This improvement ensures seismic stability of the structure during a strong earthquake. Hence, column confinement is an important component of earthquake resistant reinforced concrete buildings.

It is quite uneconomical to design a structure to respond in the elastic range to the greatest likely earthquake induced inertia forces since the maximum response acceleration may be several times the maximum ground acceleration, depending on the stiffness of the structure and magnitude of damping. This suggests the necessity of designing structures in way that the energy can be dissipated by post elastic deformations of members, which requires certain elements to be designed for ductility and strength. As well further, it is well known that the ductile behaviour of concrete sections can be attained by carefully detailed transverse reinforcement, which improvesthe properties of concrete by confining it.

The confinement index is defined as

$$C_i = (P_b - \bar{P}_b)\,(f_v / f_c')\,\sqrt{(b/s)}$$

where, P_b is the ratio of the volume of ties to the volume of concrete, $\bar{P}_b$ is the ratio of the volume of ties to the volume of concrete corresponding to a limiting pitch (1.2 times the least lateral dimension). b is the breadth of the prism and s is the spacing of ties. Thestress in the steel bars is given by $f_v = \varepsilon_v * E_s$ and is always limited to maximum yield strength. ε_v is the strain in steel and Es is the modulus of elasticity of the steel. In the present work 6mm & 8mm steel were used for tie confinement.

1.1 Objectives of the study

- To study the stress-strain behavior of the confined concrete under axial compression.
- To study the influence of confinement on ductility factor of the confined concrete.
- To study the confinement effect on the strength of the concrete.
- To study the confinement effect on strain ratios.
- To study the mechanical characteristics such as compressive strength of standard grade concrete (M40) and high strength concrete (M70) in which both coarse & fine aggregates are replaced with waste tyre and ceramic waste tile in proportions of 4% to yield optimum performance.

1.2 Scope of the study

- Influence of confinement on stress-strain behavior of ordinary concrete and high strength concrete with waste tyre and ceramic tiles waste as a replacement to both coarse & fine aggregate has not been taken up by the earlier investigators. Hence, a detailed experimental work has been planned to study the influence of confinement on stress-strain behaviour and fill the information gap in the literature.
- The scope of the present investigation is to study the stress-strain behavior of confined standard grade concrete (M40) and high strength concrete (M70) in which each of coarse & fine aggregates are replaced with waste rubber tyre waste and ceramic tiles waste in a proportion of 4% to yield optimum performance.
- In the present study variable parameters include grades of concrete, dia of lateral ties reinforcement, number of ties and the replacement materials and 6mm mild steel bars and 8mm TMT bars are used for confinement.

2. SUMMARY OF LITERATURE REVIEW

- Based on the literature review, the mild steel and TMT bars have been used for confinement of rubberized concrete and ceramic waste concrete.
- A comprehensive review of past work in the area of confinement, stress-strain characteristics and replacing cement, fine aggregate, coarse aggregate by alternate methods has been reviewed and an appraisal of review is presented.

3. MATERIALS AND TECHODOLOGY

3.1 Materials used

The different materials used in producing concrete mixes required in this work are

- 53 grade ordinary Portland cement
- G.I wire
- Steel reinforcement bars
- Coarse aggregate
- Fine aggregate
- Water
- Waste rubber tyre
- Ceramic tile waste
- Super plasticizer (SP 430)
- Silica fume

3.2 Evaluation of Mix proportions

The final mix proportions were arrived at on the trial and error method by trying variousproportions of silica fume & super plasticizer in the designed M40 & M70 concretes to achieve improvement in compressive strength. All through this experimental program, the ACI method was adopted for the design of control mix. The designed proportions of control mix (by weight) were 1 : 1.43 : 1.79 : 0.38 (cement : sand : crushed granite : W/C) and 1 : 0.76 : 1.53 : 0.28 (cement : sand : crushed granite : w/c) for M40 & M70 grade concrete respectively. Tables (3.1 & 3.2) show the quantities of ingredients for control mix (S-0, H-0) and concrete mixes containing ceramic tile waste (ST-4, HT-4) and waste rubber tyre (SR-4, HR-4) an optimum mix (per m^3) of M40 & M70 concrete mixes.

Table -1 Ingredient content of concrete mixes (kg/m^3)-M40 grade concrete

Mix code	cement	Silica fume	Fine aggregate	Fine rubber tyre waste	Coarse aggregate	Coarse rubber tyre waste	Water
S-0	526.3	0	739.53	0	930.56	0	200
SR-4	505.2	21.05	709.95	29.58	893.33	37.22	200

Table -2 Ingredient content of concrete mixes (kg/m^3)-M70 grade concrete

Mix code	Cement	Silica fume	Fine aggregate	Fine Rubber Tyre waste	Coarse aggregate	Coarse rubber tyre waste	Water	Super plasticizer (ml)
H-0	668.12	27.84	532.77	0	1046.88	0	181	7655.56
HR-4	668.12	27.84	511.46	21.31	1005.2	41.9	181	7655.56

3.3 Mixing and casting of concrete

A standard pan mixer of 50 lit capacity was used for mixing the concrete. Initially, all the dry materials (Coarse aggregate, fine aggregate, cement, silica fume and waste glass) were mixed for about two minutes. Super plasticizer was thoroughly mixed with water and the liquid component was added to the mixture of dry materials and mixed for about three minutes. Care was exercised for all the materials to get uniformly mixed up without getting stuck up to the walls of the mixer.

The prepared cage of reinforcement was carefully kept in the moulds of size (100 mm× 100mm × 200mm). Firstly, the uniformly mixed fresh concrete was poured in cast iron moulds of prisms (100mm × 100mm × 200 mm) up to one third height and then aneedle vibrator was used to compact the core concrete.

The mould was filled in three layers and compacted using the same technique to cast the specimens. the top face of the prism specimen was decoupled 24 hours after casting and cured for 28 days in the waterfor determining compressive strength and stress-strain characteristics of confined concretes containing waste rubber tyre as both coarse & fine aggregate and waste ceramic tile as both coarse & fine aggregate also.

Table -3 Slump values of fresh M40 and M70 grade concrete

S.no		Designation of mix	Slump		Designation of mix	Slump
1	M-40	S	0	M-70	H	0
2		SR	12		HR	5
3		ST	8		HT	4

4. RESULTS AND DISCUSSION

Table -4 Physical properties of OPC-53

S.No.	Property	Test Method	Test Result
1	Normal consistency	Vicat apparatus (IS 4031-Part IV)	34%
2	Specific gravity	Specific gravity bottle (IS 4031-Part II)	3.15
3	Initial setting time	Vicat apparatus (IS 4031-Part V)	45 min
4	Final setting time	Vicat apparatus (IS 4031-Part V)	175 min
5	Fineness	Sieve test on sieve no.9 (IS 4031-Part IV)	6%

Table -5 Physical Properties of conventional CA, FA & Waste Tyre Rubber, Ceramic Waste Tile

S. No	Property	Conventional coarse aggregate	Fine aggregate	Waste tyre rubber (FA)	Waste tyre rubber (CA)	Waste ceramic
1	Specific Gravity	2.79	2.67	1.79	1.13	2.34
2	Bulk density	1.47g/cc	1.298g/cc	0.42g/cc	0.47g/cc	1.33
3	Fineness Modulus	7.195	2.65	4.3	7.63	6.98
4	Water Absorption	0.48%	1%	2%	0.99%	0.36%

From the experimental observations for a given specimen, the longitudinal deformation was calculated from the average reading of the two dial gauges of the compressometer. As there is no severe spalling in concrete specimens until the load dropped by about 20- 25% of peak load, the specimens were treated dimensionally stable and hence the gross cross-sectional area is used in calculating the stress values. The stress-strain curves weredrawn for three companion specimens of a set with the same origin and the average curve was considered to represent the set.

The stress-strain curve is not linear for both M40 & M70 grade concretes and it was linear at small strains. The ductility concrete was found to increase with the increase in level of confinement. The Shah and Rangan (1970) reported that for the vertical spacing between the stirrups greater than or equal to one half of the specimen dimension, the confinement provided by the laterals becomes negligible. An examination of stress-strain diagrams for the specimens of same no. of ties & grade of concrete displayed similar stress-strain behavior for all specimens irrespective of the replacement material used. The load carrying capacity of confined concrete was foundto increase with the increase in the level of confinement. While compared to normal concrete and ceramic waste tiles concrete, rubberized concrete displayed slightly lower performance under confinement. The load carrying capacity of concrete specimens with two ties is found to be almost same as that of unconfined concrete. The specimens with 5 ties of 8mm diameter reinforcement were undergoing good ductility when compared to others. The specimen failed due to sustained vertical cracks and the deformations were high at the time of failure.

Table -6 Compressive strength of concrete-M40 and M70 grade

S. No		Designation of the mix	Compressive strength (N/mm2) 28 days		Designation of the mix	Compressive strength (N/mm2) 28 days
1	M40 grade	S	5.31	M70 grade	H	72.32
2		SR	49.9		HR	70.09
3		ST	52.2		HT	71.11

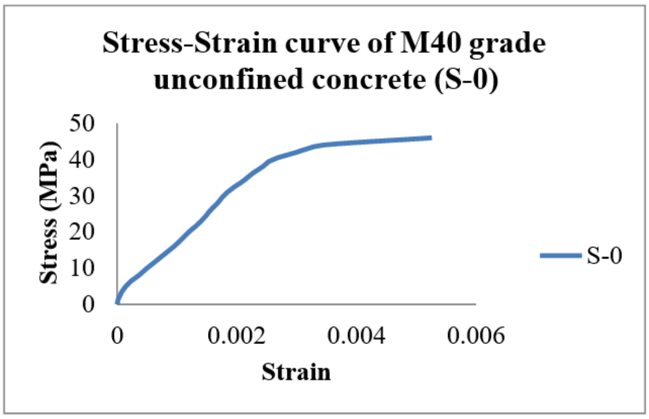

Chart -1: Stress-Strain curves for standard grade concrete (M40)

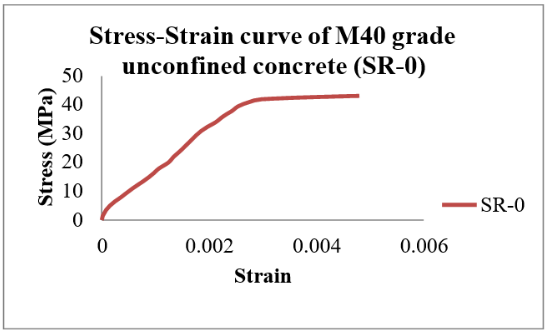

Chart-2: Stress-strain behavior of unconfined rubberized M40 grade concrete

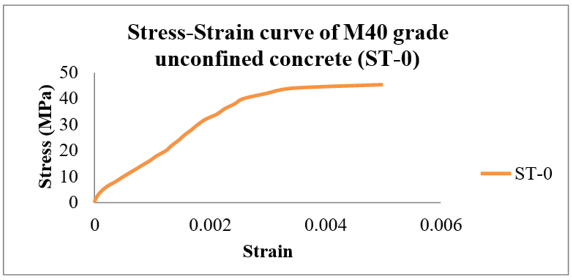

Chart-3: Stress-strain behavior of unconfined M40 grade concrete with ceramic waste

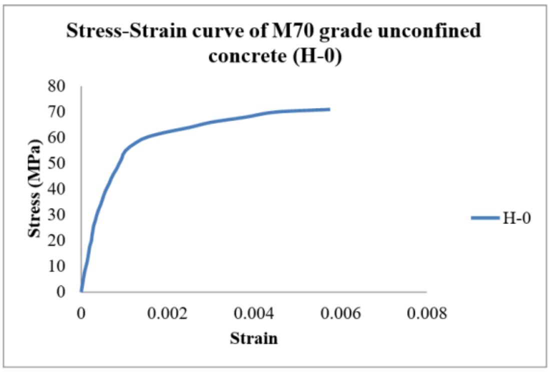

Chart-4: Stress-strain behavior of unconfined M70 grade concrete

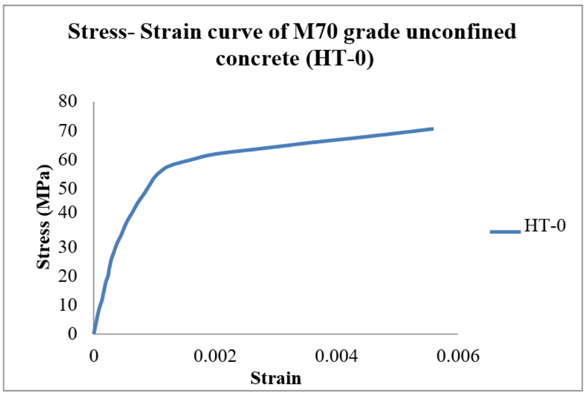

Chart-5: Stress-strain behavior of unconfined M70 grade concrete with ceramic wastetiles

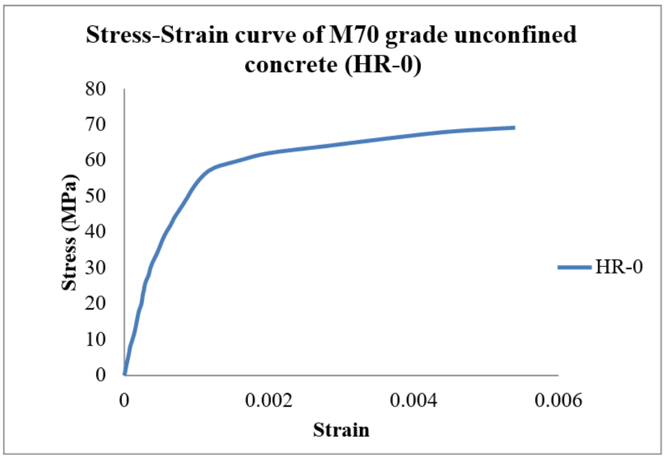

Chart-6: Stress-strain behavior of unconfined M70 grade concrete with waste rubbertyre

4. CONCLUSIONS

- Confinement of concrete using lateral ties increases the peak load, peak stress and peak strain at 85% of peak stress.
- The peak stress, peak strain, ultimate strain and ductility were almost same for the conventional concrete, waste rubber tyre concrete and ceramic waste concretes for prisms of given grade of concrete, tie spacing & diameter tie reinforcement.
- The ascending portion of the stress-strain curves changed very slightly, while the descending portion has been less steep, resulting in higher ductility.
- The ductility factor of concrete will increase with the increase in no. of ties. The smaller the spacing of the tie, the greater will be the confinement index at the same cross-sectional dimension.
- The ductility of concrete depends on quality of concrete and greater the quality of concrete used, smaller will be the confinement index for the same tie spacing.
- The load carrying capacity of concrete increased with the increase in level of confinement, i.e. confinement index (Ci).
- The stress ratio, strain ratio and ductility factor increased with an increase in the confinement index.
- Companion cubes tested at 28-days of conventional curing yielded Both M40and M70 grade concretes with and without replacements showed good compressive strength.

4.1 Scope of future investigation

- Investigations can be carried out with different sizes of specimens with different confinement index.
- Investigations can be carried out for developing the stress block parameters and moment curvature relationship.
- Investigations can be carried out combining recycled aggregate and waste ceramic tiles and waste tyre rubber.

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