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STUDY OF MECHANICAL PROPERTIES OF HOLLOW CIRCULAR TUBULAR SECTIONS WITH AND WITHOUT FRP

GUDLURU R DINESH
PG Student: Department Of Civil Engineering Siddarth Institute of Engineering and Technology, Andhra Pradesh, India.
gudlurudinesh@gmail.com

J.K.ELUMALAI
Asst. Professor: Department Of Civil Engineering Siddarth Institute of Engineering and Technology Andhra Pradesh, India.
jkelumalai@gmail.com

ABSTRACT:

The present research concentrates about compare the behaviour of concrete filled FRP tubes under different grades of concrete. Evaluate the behaviour of concrete filled FRP tubes using central holes with and without an inner PVC pipe. To evaluate both fully and partially concrete filled FRP tubes attain the axial compressive strength, tensile load and Modulus of elasticity. Comparison of strengths for the above cases and suggesting the effectiveness of FRP.

Compared with conventional concrete cylinders, FRP tubes filled with concrete attains a compressive strength, which is 87 % higher that of conventional concrete cylinders. Strength and ductility are greatly improved by filling the tubes with concrete. FRP tubes were more efficient than steel tubes in this regard. Concrete in the compression zone is partially confined as evident by the lateral tensile strains measured on the shell. If the hole is maintained by an inner PVC pipe, the confinement effectiveness is improved and could approach that of a totally filled tube. It can be observed that there is significant improvement in Cylinder Compressive Strength, Split Tensile Strength and Modulus of Elasticity compared to PVC Shells. The Percentage increase in Compressive Strength for M20 Grade of Concrete with Central Hole dia of 0mm, 50mm & 75mm are 87.76%, 54.31% and 71.11 respectively. Similarly, for M25 Grade of Concrete with Central Hole dia of 0mm, 50mm & 75mm are 106.93%, 81.79% and 93.46% respectively.

KEYWORDS: Axial compression test,Split tensile strength and Modulus of Elasticity.

I. INTRODUCTION:

There is a great appeal for columns and piles to be constructed using more durable materials in comparison to traditional construction materials. The contemporary products have to withstand destructive corrosive environments, such as the splash zone in the case of marine piles. Correspondingly, bridge columns have to retain their structural integrity in cold regions where salt is used for de-icing roads. One auspicious inventive structural system is concrete-filled Fibre Reinforced Polymer (FRP) tubes, which provide many unique advantages. The FRP tube serves as a stay-in-place structural formwork to contain the fresh concrete, which may save the costs of formwork and labour used by cast-in-place or pre- cast industries. In the meanwhile, the FRP tube acts as a non-corrosive reinforcement for the concrete for flexure and shear. More importantly, the FRP tube arrests the concrete in compression, which somewhat improves the strength and ductility. The FRP tubes which are filled with concrete are effective in facing the great appeal for non-corrosive and durable piles, power transmission poles, highway overhead sign structures and bridge components.

Concrete-filled steel tubes have been utilized for years as piles and columns. Abundant researches has been established in this direction [Furlong 1967, Knowles and Park 1969, and Kilpatrick and Rangan 1997]. It should be noted, nonetheless, that in addition to the rusting problems of steel tubes, the confinement capability is reduced at low levels of loading if the tube is loaded in the axial direction. This is associated to the evidence that Poisson's ratio of concrete at low levels of loading, 0.15 to 0.2, is lesser than the 0.3 assessment of steel [Prion and Boehme 1994 and Wei et al 1995]. On the other hand, Poisson's ratio of FRP tubes can be controlled through selected design of the laminate structure to provide more confinement effect [Shahawy and Mirmiran 1998].

The confining pressure affords by steel tubes is limited to a constant value once the tube yields, whereas FRP tubes affords a continuously increasing confining pressure, which adds to both the ultimate confined strength and ductility [Samaan 1998].

For practical reasons, FRP tubes which are filled with concrete are used to carry axial compression loads and may also be designed to resist bending moments. Most of the reported experimental and analytical research in the area of concrete confinement using FRP [Mirmiran et al 1998] included FRP tubes totally filled with concrete and the fibres were mainly oriented in the hoop direction to provide maximum stiffness and strength for confinement. Other studies treated, that the case of applying the axial

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load to the concrete core only for an optimum use of the FRP tube in the hoop direction for confinement [Mirmiran and Shahawy 1997]. In such case, slip could take place between, the concrete and the outer tube, and consequently the member cannot resist bending. Arresting of concrete cylinders which are wrapped with FRP sheets and subjected to axial loading conditions was also studied by other researchers [Nanni and Bradford 1995 and Picher et al 1996]

2 MATERIALS AND PROPERTIES:

2.1 CEMENT:

Cement acts as a dominant role in concrete. One of the important criteria tricalcium aluminate (C_3A) content, tricalcium silicate (C_3S) content, dicalcium silicate (C_2S) content etc. It is also necessary to ensure the compatibility of chemical and mineral admixtures with cement.

In this study, Zuari Cement of 53 grade Ordinary Portland Cement conforming to IS: 12269–1987 is used for the entire work. The cement was purchased from single source and was used for casting of all specimens. The physical properties of the cement are furnished in Table No.1

Table 1 Physical properties of the cement

S.No	Characteristics	Test Results	Requirements as per IS 12269 - 1987
1	Fineness (retained on 90-µm sieve)	6%	<10%
2	Normal Consistency	33%	--
3	Initial setting time of cement	90 min's	30 minutes (minimum)
4	Final setting time of cement	340 min's	600 minutes (maximum)
5	Expansion in Le-chatelier's method	4 mm	10 mm (maximum)
6	Specific gravity	3.15	3.10 – 3.25

2.2 FINE AGGREGATE:

The natural sand taken for this investigation is the local natural river sand. It was collected and cleaned for impurities, so that it is free from clayey matter, salt and organic impurities. Particles passing through IS sieve of 4.75 mm conforming to grading zone-II of IS: 383-1970 were used in this work. Properties such as gradation, specific gravity, fineness modulus, bulking, and bulk density had been assessed. The physical properties of sand are furnished in Table 2.

Table 2 Physical properties of the Fine Aggregate

S.No.	Tests Conducted	Results Obtained		Permissible Limits as per IS 383-1970
1	Specific gravity	2.67		2.5 to 3.0
2	Fineness modulus	3.05		--
3	Bulk density	Loose State	1450 kg/m³	1400 to 1750 kg/m3
		Compacted State	1520 kg/m³	
4	Water absorption (%)	1.09		Max 3%
5	Sieve Analysis	Zone – II		--

2.3 COARSE AGGREGATE:

Locally available machine Crushed angular granite, retained on 4.75mm I.S. Sieve of maximum size of 20mm confirming to I.S: 383-1970 was used in the present experimental investigation. It should be free from impurities such as dust, clay particles and organic matter etc. The coarse aggregate is tested for its various properties such as specific gravity, fineness modulus, elongation test, flakiness test, sieve analysis, bulk density in accordance with in IS 2386 – 1963. The physical properties of Coarse Aggregate are furnished in Table 3.

Table 3 Physical properties of Coarse Aggregate

S.No.	Tests Conducted	Results Obtained		Permissible Limits as per IS 383-1970
1	Specific gravity	2.78		2.5 to 3.0
2	Fineness modulus	7.52		--
3	Bulk density	Loose State	1480 kg/m³	1400 to 1750 kg/m3
		Compacted State	1560 kg/m³	
4	Water absorption (%)	1.09		Max 3%
5	Flakiness Index	7.52		--
6	Elongation Index	20%		Max 25%

2.4 WATER:

Water which is used for mixing and curing should be clean and free from injurious quantities of alkalies, acids, oils, salts, sugar, organic materials, vegetable growth (or) other substance that may be deleterious to bricks, stone, concrete, or steel. Convenient water is generally considered satisfactory for mixing.

Water acts as a lubricant for the fine and coarse aggregates and acts chemically with cement to form the binding paste for the aggregate and reinforcement. Less water in the cement paste will yield a stronger, more durable concrete; adding too much water will reduce the strength of concrete and can cause bleeding. Impure water in concrete, effects the setting time and causes premature failure of the structure. To avoid these problems quality

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water must be selected in construction works and PH value of water should be not less than 6. And also Quantity of water to be taken is important

2.5 FIBRE REINFORCED POLYMER:

FRP composite is a two phased material. It consists of fibre and matrix, which is bonded at interface. Each of these different faces, has to perform its required function based on mechanical property, so that the composite system performs satisfactorily as a whole. Here the reinforcing fibre provides FRP composite with strength and stiffness, while it gives rigidity and environmental protection.

2.6 MIX PROPORTIONS:

Table 4 Quantities of Ingredients per Cum of M20, M25 Grade Concrete

Concrete	Cement (Kg)	Water (Lit)	Fine Aggregate (kg)	Coarse Aggregate (Kg)
M 20	330	180	744	1212
M 25	340	170	662.4	1183

3 EXPERIMENTAL INVESTIGATIONS:

3.1 CONCRETE MIX PREPARATION:

Design of concrete mix requires complete knowledge of various properties of the constituent materials. Initially the ingredients such as cement and fine aggregate were mixed, to which the coarse aggregate are added followed by addition of water and thoroughly mixed. Prior to casting of specimens, workability is measured in accordance with the code IS 1199-1959 by slump cone test

3.2 CYLINDER COMPRESSIVE STRENGTH:

Cylinder Compressive Strength test was conducted on cylindrical specimens at 28 days as per IS 5816-1999. All the concrete cylinder specimens were tested in compression-testing machine. Three cylindrical specimens of size 150 mm × 300 mm were casted. The load was applied eventually till the failure of the specimen happens. Compressive Strength of concrete is determined by applying load at the rate of 140kg/sq.cm/minute till the specimens failed. The maximum load applied was then noted. Fig 5.1 shows the position of the concrete cylinder placed in the compression testing machine. The cylinder compressive strength is calculated by using the formula

$$\text{Comp strength } (N/mm^2) = \frac{\text{Ultimate compressive load } (N)}{\text{Area of cross section of specimen} (mm^2)}$$

3.3 SPLIT TENSILE STRENGTH:

Split Tensile Strength test was conducted on cylindrical specimens at 28days as per IS 5816-1999. Three cylindrical specimens of size 150 mm × 300 mm were casted. Split tensile strength of concrete is determined by applying the load at the rate of 140kg/sq.cm/minute till the specimens failed. The maximum load was applied then noted.

The splitting tensile strength (Ft) was calculated as follows:

$$Ft = \frac{2P}{\pi DL}$$

Where, P = Compressive load
L = Length of the cylinder
D = Diameter of the cylinder

3.4 MODULUS OF ELASTICITY:

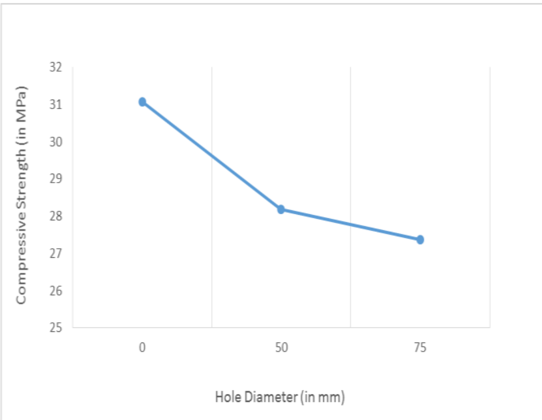
Compress meter with dial gauge is used to determine the modulus of elasticity of concrete, using cylinders of diameter 150 mm and height of 300 mm. Compressometer contains two steel rings which is used for clamping to the specimen, two gauge length bars, dial gauge and spherically seated lever unit. The unit is clamped to the specimen by means of screws fitted on the upper and lower rings. When the unit is attached to the specimen the gauge length bars are removed and the dial gauge set to zero for the test. Load should be applied gradually, and corresponding dial gauge readings were noted. Strain is calculated using dial gauge reading and gauge length of the specimen. Modulus of Elasticity is calculated from the graph drawn for stress and strain

4 RESULTS AND DISCUSSIONS:

4.1 TEST RESULTS FOR M20 GRADE OF CONCRETE:

4.1.1 COMPRESSIVE STRENGTH:

Fig 1 shows the variation of Compressive Strength of M20 Grade of Concrete with PVC Shell and With Fibre Reinforced Polymer Shell with Central Holes of 0mm, 50mm & 75mm. It can be observed that there is significant improvement in Cylinder Compressive Strength compared to PVC Shells. The Percentage increase in Compressive Strength for Central Hole dia of 0mm, 50mm & 75mm are 87.76%, 54.31% and 71.11 respectively



(I) PVC

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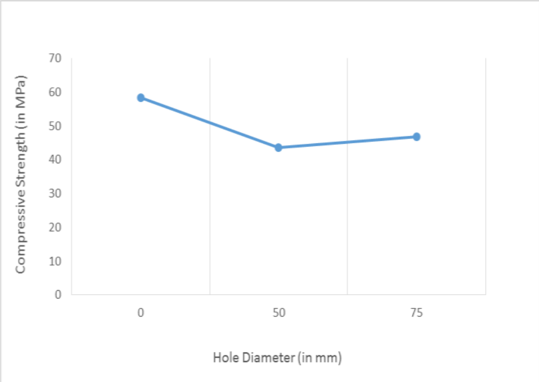
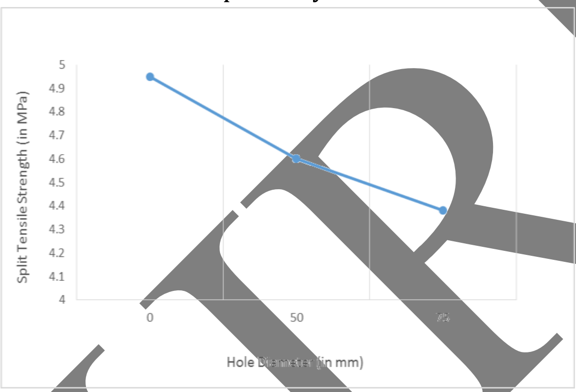


(II) FRP

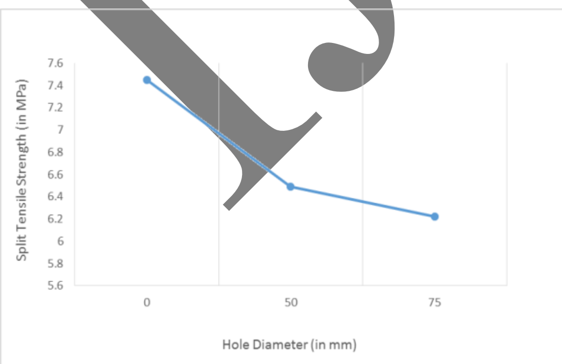
Fig 1 Variation of Cylinder Compressive Strength of M20 Grade of Concrete with PVC and FRP Shell with Central Holes with diameter 50mm & 75mm

4.1.2 SPLIT TENSILE STRENGTH:

Fig 2 shows the variation of Split Tensile Strength of M20 Grade of Concrete with PVC Shell and With Fibre Reinforced Polymer Shell with Central Holes of 0mm, 50mm & 75mm. It can be observed that there is significant improvement in Split Tensile Strength compared to PVC Shells. The Percentage increase in Split Tensile Strength for Central Hole dia of 0mm, 50mm & 75mm are 50.50%, 41.08% and 42.00% respectively



(I) PVC

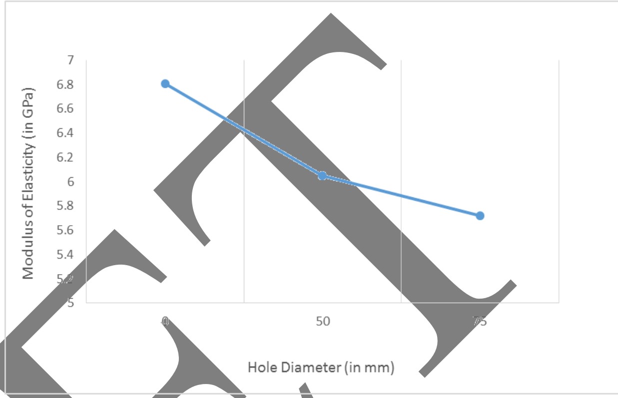


(ii) FRP

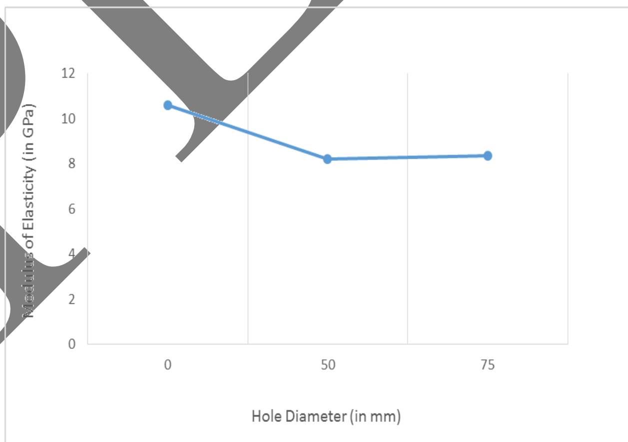
Fig 2 Variation of Split Tensile Strength of M20 Grade of Concrete with PVC and FRP Shell with Central Holes with diameter 50mm & 75mm

4.1.3 MODULUS OF ELASTICITY:

Fig 3 shows the variation of Modulus of Elasticity of M20 Grade of Concrete with PVC Shell and With Fibre Reinforced Polymer Shell with Central Holes of 0mm, 50mm & 75mm. It can be observed that there is significant improvement in Modulus of Elasticity compared to PVC Shells. The Percentage increase in Modulus of Elasticity for Central Hole dia of 0mm, 50mm & 75mm are 50.55%, 35.53% and 45.80% respectively.



(i) PVC



(ii) FRP

Fig No.3 Variation of Modulus of Elasticity of M20 Grade of Concrete with PVC and FRP Shell with Central Holes with diameter 50mm & 75mm

4.2 TEST RESULTS FOR M25 GRADE OF CONCRETE:

4.2.1 COMPRESSIVE STRENGTH:

Fig 4 shows the variation of Compressive Strength of M25 Grade of Concrete with PVC Shell and With Fibre Reinforced Polymer Shell with Central Holes of 0mm, 50mm & 75mm. It can be observed that there is significant improvement in Cylinder Compressive Strength compared to PVC Shells. The Percentage increase in Compressive Strength for Central Hole dia of 0mm, 50mm & 75mm are 106.93%, 81.79% and 93.46% respectively

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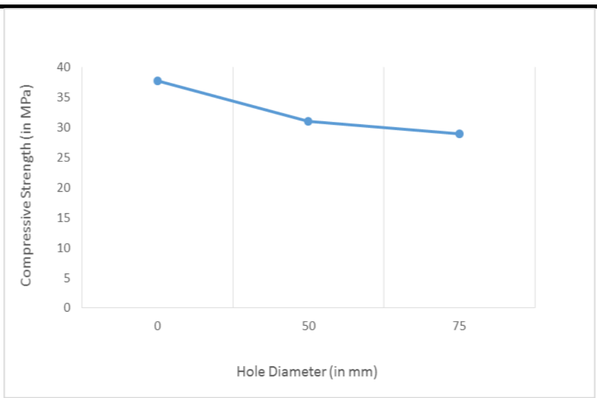
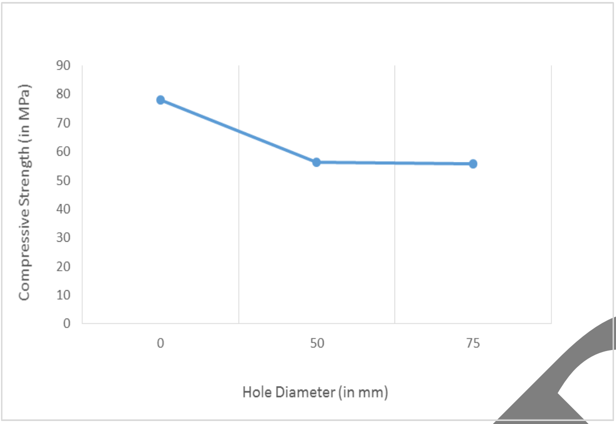


(i) PVC

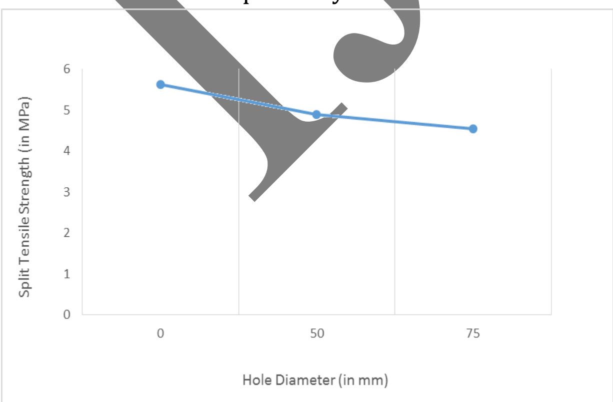


(ii) FRP

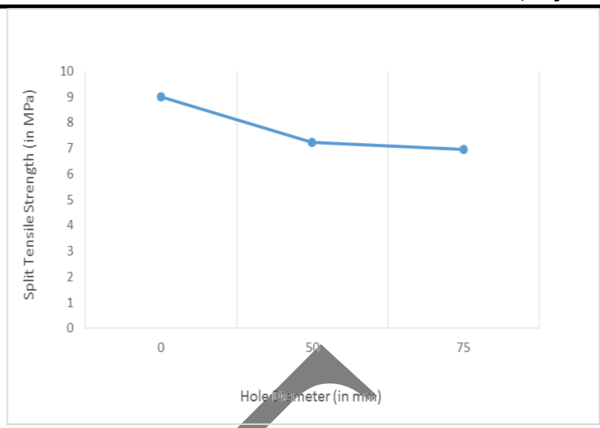
Fig .4 Variation of Cylinder Compressive Strength of M25 Grade of Concrete with PVC and FRP Shell with Central Holes with diameter 50mm & 75mm

4.2.2 SPLIT TENSILE STRENGTH:

Fig 5 shows the variation of Split Tensile Strength of M25 Grade of Concrete with PVC Shell and With Fibre Reinforced Polymer Shell with Central Holes of 0mm, 50mm & 75mm. It can be observed that there is significant improvement in Split Tensile Strength compared to PVC Shells. The Percentage increase in Split Tensile Strength for Central Hole dia of 0mm, 50mm & 75mm are 60.32%, 47.65% and 53.52% respectively.



(i) PVC

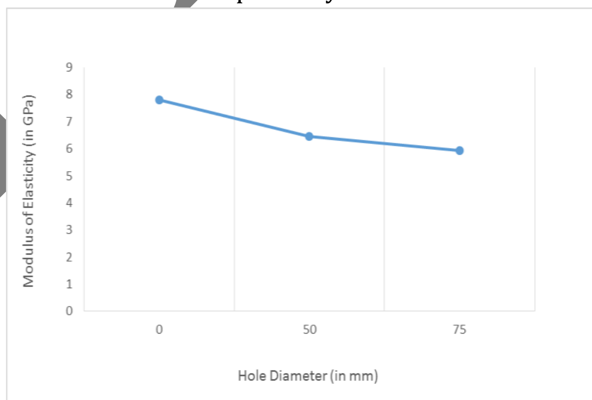


(ii) FRP

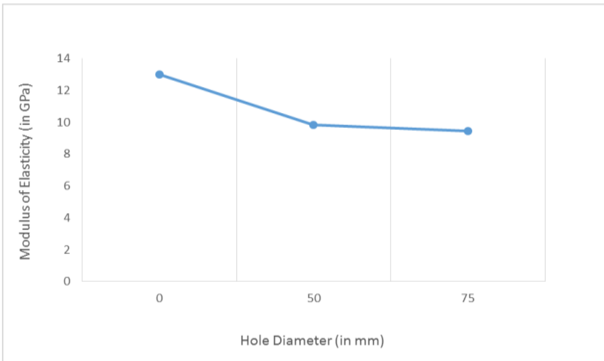
Fig.5 Variation of Split Tensile Strength of M25 Grade of Concrete with PVC and FRP Shell with Central Holes with diameter 50mm & 75mm

4.2.3 MODULUS OF ELASTICITY:

Fig 6 shows the variation of Modulus of Elasticity of M25 Grade of Concrete with PVC Shell and With Fibre Reinforced Polymer Shell with Central Holes of 0mm, 50mm & 75mm. It can be observed that there is significant improvement in Modulus of Elasticity compared to PVC Shells. The Percentage increase in Modulus of Elasticity for Central Hole dia of 0mm, 50mm & 75mm are 66.58%, 52.32% and 58.92% respectively.



(i) PVC



(ii) FRP

Fig No.3 Variation of Modulus of Elasticity of M20 Grade of Concrete with PVC and FRP Shell with Central Holes with diameter 50mm & 75mm

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5 CONCLUSIONS:

1. Totally filled FRP tubes provide the most effective confinement. Although an inner hole offers material saving and reduced self-weight, it reduces the confinement effect, even though, high level of ductility is maintained.
2. Compared with conventional concrete cylinders, FRP tubes filled with concrete attains a compressive strength, which is 87 % higher that of conventional concrete cylinders
3. Strength and ductility are greatly improved by filling the tubes with concrete. FRP tubes were more efficient than steel tubes in this regard.
4. Concrete in the compression zone is partially confined as evident by the lateral tensile strains measured on the shell.
5. If the hole is maintained by an inner PVC pipe, the confinement effectiveness is improved and could approach that of a totally filled tube
6. It can be observed that there is significant improvement in Cylinder Compressive Strength, Split Tensile Strength and Modulus of Elasticity compared to PVC Shells.
7. The Percentage increase in Compressive Strength for M20 Grade of Concrete with Central Hole dia of 0mm, 50mm & 75mm are 87.76%, 54.31% and 71.11 respectively.
8. Similarly for M25 Grade of Concrete with Central Hole dia of 0mm, 50mm & 75mm are 106.93%, 81.79% and 93.46% respectively
9. The Percentage increase for M20 Grade of Concrete in Split Tensile Strength for Central Hole dia of 0mm, 50mm & 75mm are 50.50%, 41.08% and 42.00% respectively. Similarly for M25 the percentage improvements in Split Tensile Strength for Central Hole dia of 0mm, 50mm & 75mm are 50.50%, 41.08% and 42.00% respectively
10. The Percentage increase for M20 Grade of Concrete in Modulus of Elasticity for Central Hole dia of 0mm, 50mm & 75mm are 50.55%, 35.53% and 45.80% respectively.
11. Similarly for M25 the percentage improvements in Modulus of Elasticity for Central Hole dia of 0mm, 50mm & 75mm are 66.58%, 52.32% and 58.92% respectively

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