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DESIGN AND COMPARITIVE ANALYSIS OF CONVENTIONAL SLAB AND VOIDED SLAB LIGHTENED WITH POLYPROPYLENE

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Abstract - *The present project discusses the structural behaviour of voided slab lightened with recycled polypropylene moulds and their structural benefits over traditional concrete slab. Voided slab is a method of virtually eliminating the portion of concrete from the middle of a floor slab, which is not performing any structural function, thereby reducing structural self-weight. Polypropylene moulds replace the ineffective concrete in the centre of slab. By introducing the gaps leads to a 30 to 40 % lighter slab which reduces the slab thickness. In this project laboratory tests were done on the materials and tests were performed on concrete with and without polypropylene with varying percentages. Analysis was done in ANSYS 16.2 to compare the conventional slab and voided slab by incorporating polypropylene moulds in the slab to determine the stress, strain and deformation and also to carry out the cost of the conventional and voided slab.*

Key Words: Flat Slab, Polypropelene, Voided Slab.

1. INTRODUCTION

This report examines the design process of plastic voided slabs. The principles behind plastic voided slab systems are presented. A parametric study of one-way flat plate reinforced concrete slabs and plastic voided slabs with the same design constraints is discussed. Plastic voided slabs remove concrete from non-critical areas and replace the removed concrete with hollow plastic void formers while achieving similar load capacity as solid slabs. Voided slab principles have been applied in different applications dating back to the early 1900s.

1.1 Objectives

i. The primary goal of the study is to prove that U-Boot Beton technology is also suitable for one-way slab system rather than U-Bhan Beton Technology according to Daliform group.
ii. To Analyse relative weight, thickness and strength parameters of a plastic voided slab and the solid flat slab.
iii. To Analyse the Cost of both the Slab.

1.2 Literature Review

A lot of researchers similar to this type of project have been contributed towards the field, Brief review of literature relevant to the study is presented below.

Roberto Il Grande (2001) - Developed and patented a new system of hollow formers, in order to decrease the transportation costs (and CO2 production). The U-Boot formwork is a modular element made of re-cycled plastic for use in building lighter structures in reinforced concrete cast at the work-site. The biggest advantage of U-boot is that it is stackable. A truck of U-boot means approximately 5000 m2 of slab, once hollow formers are laid down at building site. The second innovation is the shape: U-boot creates a grid of orthogonal "I" beams, so the calculation of the reinforcement can be affected by any static engineer according to Euro code, British Standards or any local standard.

Northam R et al. (2009) - In this paper, the slabs are made with plastic ball to reduce the self-weight of the structure. The main aim of this paper is to give a report about punching shear on voided slabs with plastic balls. Since the punching shear limit is the most important property of flat slab, this paper studies about the punching shear on plastic balls. This paper used steel fibres with 0.8% and 1% for defining punching load and deflection. This paper concludes for voided slab, the punching strength with steel fibre 0.8% and 1% is increased by 2.56% and 7.7% respectively on comparison with voided slab without steel fibre. Also, the deflection increased by 3.153% and 15.243% respectively.

Harishma K.R et al. (2015) - In this paper, an experimental study is carried out on bubble deck slab made with elliptical balls made of polyethylene. This paper gives a report regarding deflections for four different types of slabs i.e. conventional slab, continuous slab, alternative slab with zigzag arrangement and alternative slab with regular arrangement. On comparing 4 types of slabs the load carrying capacity is more for continuous slab i.e. 320 KN. On comparison the deflection is more for continuous slab.

2. MATERIALS

2.1. Concrete:

The concrete used for joint filling in the Voided slab system must be above M20-M25 grade. The nominal maximum size of the aggregate is the function of the thickness of the slab.

Table -1: Properties of Concrete M25

Property	Value
Modulus of Elasticity in MPa	2500
Compressive ultimate strength in MPa	25
Poisson's ratio	0.2

2.2. Reinforcement Bars:

The reinforcement of the plates is made of two meshes, one at the bottom part and one at the upper part that can be tied or welded. Grade Fe-415 strength or higher is used.

Table -2: Properties of Steel Fe-415

Property	Value
Modulus of Elasticity in MPa	200000
Compressive ultimate strength in MPa	500
Poisson's ratio	0.3

2.3. Polypropylene Moulds (U-Boot Beton):

i. Polypropylene(C3H6) n is a recycled material which is obtained by a recycled plastic industrial waste. It is a by-product of plastic industry. It is discovered in the middle 1950's by Italian scientists.
ii. It contains three carbon molecules and six hydrogen molecules. Due to its chemically inert nature it does not react with any of the materials like water, cement, admixtures etc.
iii. when it is placed in concrete, it has high melting point and hence, it can be used in construction industry. As it is a flexible material, it is resistant to cracks and stress.
iv. The polypropylene has very low density and it is the reason for the light weight of the slab constructed using u-boot beton.
v. The sizes of U-boot beton varies based on the mode of work and based on the load acting on the beton. The general working cross sectional dimensions of the U-boot beton is 52*52cms.

Fig -1: U-boot Beton Box

Table -3: Properties of Polypropylene

Property	Value
Density in kg/m^3	902
Coefficient of Thermal Expansion in °C	0.000103
Poisson's ratio	0.443
Young's Modulus in Pa	9.15x10^8
Bulk Modulus in Pa	2.6754x10^9
Shear Modulus in Pa	3.1705x10^8
Tensile Yield Strength in Pa	2.62x10^7
Tensile Ultimate Strength in Pa	2.99x10^7

3. Methodology

3.1. Methodology of Test Specimen:

i. Casted and tested samples of concrete with and without polypropylene fibre to compare the strengths. The methodology used for the test specimens is IS Method for Concrete Mix Design.
ii. The Mix design for M25 grade of concrete for both Conventional Specimen and the concrete specimen with polypropylene fibre's used is shown below according to concrete mix design IS 10262-2009.

Table -4: Design stiplulation

Grade Designation	M25
Type of cement	OPC 53 Grade Conforming to IS-2269-1987
Maximum nominal size aggregate, mm	20
Minimum cement content	300 kg/m^3
Maximum water cement ratio	0.4
Exposure condition	Normal
Degree of super vision	Good
Type of aggregate	Crushed Angular aggregate

Table -5: Test Data for Materials

Cement used	opc 53 grade
SP.Gravity of cement	3.15
SP.Gravity of Water	1
SP.Gravity of 20 mm aggregate	2.6
SP.Gravity of sand	2.68
Water absorption of 20 mm aggregate	0.97%
water absorption of sand	1.23%
Free surface moisture of aggregate and sand	nill

Table -6: Selection of Materials

Target strength for Mix Proportioning	
Characteristic Strength at 28 days	20
Target Mean Strength f_{ck} + 1.65* t*s	26.6N/mm²
Selection of water cement ratio	
Maximun water cement ratio	
Adopted Water cement ratio	0.40
Selection of water content	
According to code IS 10262 2009	
Maximum water content	208Lit
Estimated water content for slump (25-50)mm	208Lit
Calculation of Cement content	
Water cement ratio	0.40
Cement Content(Water)/(w/c)Ratio	520Kg
Proportion of Volume of Coarse aggregate and Fine aggregate	
Volume of Coarse Aggregareas per table 3 of IS 10262-2009	66%
Adoptedvolume of Coarse aggregate	66%
Adoptedvolume of Fine aggregate	34%

Table -7: Calculation of Mix Proportion

Mix Calculations	
Volume of Concrete	1M³
Volume of Cement(Mass of cement)/(sp.gravity of cement)*1000	0.165M³
volume of Water(Mass of Water)/(sp.gravity of Water)*1000	0.208M³
Volume of all In Aggregate	0.627M³
Volume of Coarse Aggregate	0.414M³
Volume of Fine Aggregate	0.213M³
Mix Proportion For 1 Cum Of Concrete	
Mass of Cement	520
Mass of Fine Aggregate	571
Mass of Coarse aggregate	1076
Mass of Water	208
Water cement ratio	0.40
1:1.09855785103785:2.06883809523	

Table -8: Quantity of Materials for Conventional Concrete Specimen

M25 For 1 Cube (15cm)			**M25 For 1 Beam (50*10cm)**		
Proportion for M25 Grade 1:1.09:2.06					
Cement	1		Cement	1	
Sand	1.09		Sand	1.09	
Coa agg	2.06		Coa agg	2.06	
water	1.060240964		water	1.626506	
		For 3Cubes			**For 3Beams**
Wt of cement	2.12kg	6.36kg	Wt of cement	3.25kg	9.76kg
wt of Sand	2.31kg	6.93kg	wt of Sand	3.55kg	10.64kg
wt of Coa agg	4.37kg	13.10kg	wt of Coa agg	6.70kg	20.10kg
wt of water	1.06lt	3.2lt	wt of water	1.63lt	4.9lt

Table -9: Materials for Cement Replaced by Polypropylene Fibre Specimen

M25 For 1 Cube (15cm)			**M25 For 1 Beam (50*10cm)**		
Proportion for M25 Grade 1:1.09:2.06					
Cement replaced by 2% of polypropelene fibre					
Cement	1		Cement	1	
Sand	1.09		Sand	1.09	
Coa agg	2.06		Coa agg	2.06	
water	0.85995		water	1.274	
		For 3Cubes			**For 3Beams**
Wt of cement	1.72kg	5.16kg	Wt of cement	2.55kg	7.64kg
wt of Sand	2.31kg	6.93kg	wt of Sand	3.55kg	10.64kg
wt of Coa agg	4.37kg	13.10kg	wt of Coa agg	6.70kg	20.10kg
wt of water	0.86lt	2.6lt	wt of water	1.27lt	3.8lt

3.2. Methodology of Slab:

Step 1: Calculation of Thickness for Slab

The depth of slab depends on bending moment and deflection criterion. The trail depth can be obtained using:

Effective depth d= Span /((L/d) x modification factor)

For obtaining modification factor, the percentage of steel for slab can be assumed from 0.2 to 0.5%.

The effective depth d of two-way slabs can also be assumed using cl.24.1, IS 456 provided short span is <3.5m and loading class is <3.5KN/m²

i. Thickness of Conventional Slab = 300/ [0.3125×32]

= 30cm

ii. Thickness of Voided Slab,

Equivalent thickness = (volume of concrete-volume of voids)/total area of slab Volume of concrete

$L \times B \times t = 800 \times 300 \times 30 =$ 72,00,000cm^3

Volume of voids = no. of polypropylene moulds used × (l×b×t) of beton

= 58× (52×52×10) = 15,68,320cm^3

Equivalent thickness = (72,00,000-15,68,320)/(800×300)

= 24cm

Step 2: Calculation of Self Weight of Slab

i. For Conventional Slab,

Self-weight of conventional slab = Thickness of slab × unit weight of RCC = 0.3 × 25 = 7.5 KN/m^2

ii. For Voided Slab,

Self-weight of Voided slab = Thickness of slab × unit weight of RCC = 0.24 × 25 = 6 KN/m^2

Step 3: Calculation of Load on Slab

i. For Conventional slab,

Dead load = Self weight of slab = 7.5KN/m^2

Floor finish (Assumed as) = 2 KN/m^2

Live load (Assumed as) = 5 KN/m^2

Wind load (Assumed as) = 1 KN/m^2

Therefore, Total load acting on the sab = (7.5 + 2 + 5 + 1) =15.5 KN/m^2

ii. For Voided Slab,

Dead load = Self weight of slab = 6 KN/m^2

Floor finish (Assumed as) = 2 KN/m^2

Live load (Assumed as) = 5 KN/m^2

Wind load (Assumed as) = 1 KN/m^2

Therefore, Total load acting on the sab = (6 + 2 + 5 + 1) =14 KN/m^2

Step 4: Calculation of Bending Moment (BM) on the Slab

i. For Conventional Slab,

BM of conventional slab $M_x = \alpha x \times w \times (L_x)^2$,

$M_y = \alpha y \times w \times (L_x)^2$

αx and αy are moment coefficients x y given in Table 27 of IS 456-2000. Ly/Lx = 800/300 =2.66

For Ly/Lx = 2.5; αx = 0.122 & αy = 0.020

Ly/Lx = 3; αx = 0.124 & αy = 0.014

Ly/Lx = 2.66; αx =? & αy =?

αx = ((0.124-0.122) x (2.66-2.5))/ (3-2.5) = 0.1226

αy = ((0.020-0.014) x (2.5-3))/ (2.66-2.5) = 0.0192

$M_x = \alpha x \times w \times (L_x)^2$ $M_y = \alpha y \times w \times (L_x)^2$

$= 0.1226 \times 15.5 \times 3^2$ $= 0.014 \times 15.5 \times 3^2$

= 17.1027 KN-m = 1.953 KN-m

Therefore, BM = 17.1027 KN-m

ii. For Voided Slab,

Ly/Lx = 800/300 =2.66

For Ly/Lx = 2.5; αx = 0.122 & αy = 0.020

Ly/Lx = 3; αx = 0.124 & αy = 0.014

Ly/Lx = 2.66; αx =? & αy =?

αx = ((0.124-0.122) x (2.66-2.5))/ (3-2.5) = 0.1226

αy = ((0.020-0.014) x (2.5-3))/ (2.66-2.5) = 0.0192

$M_x = \alpha x \times w \times (L_x)^2$; $M_y = \alpha y \times w \times (L_x)^2$

$= 0.1226 \times 14 \times 3^2$ $= 0.014 \times 14 \times 3^2$

= 15.4476 KN-m = 1.764 KN-m

Therefore, BM = 15.4476 KN-m

Step 5: Calculation of Area of Steel

i. For Conventional slab,

Mu = 0.87fy x (Ast) x d x (1-Xu max)

Where, Xu = 1-((fyxAst) (fck bd))

Mu = 0.87x 415 x Ast x 300 x (1-((415xAst)/(25x1000x300)))

$17.1027 \times 10^6 = 108315Ast - 5.99Ast^2$

Therefore, Ast = 17923.33655mm^2

ii. For Voided Slab,

Mu = 0.87fy x (Ast) x d x (1-Xu max)

Where, Xu = 1-((fyxAst)/ (fck bd))

Mu = 0.87x 415 x Ast x 240 x (1-((415xAst)/(25x1000x240)))

$15.4476 \times 10^6 = 86652Ast - 5.993Ast^2$

Therefore, Ast = 14278.34303 mm^2

Step 6: Calculation of Number of Bars Required and Spacing of Bars

i. For Conventional slab,

Number of bars required = (Ast)obtained/((π/4) x d^2)

For main reinforcement,

Where, d is the diameter of bar used = 18mm

Ast = area of steel obtained = 17923.33655mm^2

Number of bars required = (17923.33655)/((π/4) x 18^2)

= 7.85 ~ 8bars

Spacing of the bars as per IS456, should be a minimum of

a) 3d = 3x 300 = 900mm

b) ((Ast)required/(Ast)obtained) x 1000

=((π/4)x18^2)/(17923.33655mm^2)x1000=192mm~200mm

c) 300mm

Therefore, 8bars of 200mm c/c spacing is used for main reinforcement

For distributed reinforcement,

Where, d is the diameter of bar used = 16mm

Ast = area of steel obtained = 17923.33655mm^2

Number of bars required = (17923.33655)/((π/4) x 16^2)

= 16.2 ~ 17bars

Spacing of the bars as per IS456, should be a minimum of

a) 5d = 5x 300 = 1500mm

b) ((Ast)required/(Ast)obtained) x 1000

= ((π/4) x16^2) /17923.33655) x1000 =390 ~ 400mm

c) 450mm

Therefore, 17bars of 400mm c/c spacing is used

ii. For Voided Slab,

Where, d is the diameter of bar used = 6mm

Ast = area of steel obtained = 14278.34303 mm^2

Number of bars required = (14278.34303)/((π/4) x 6^2)

= 13.62 ~ 14bars

For main reinforcement,

Spacing of the bars as per IS456, should be a minimum of

a) 3d = 3x 300 = 1500mm

b) ((Ast)required/(Ast)obtained) x 1000

= ((π/4) x6^2)/ (14278.34303) x1000 = 185 ~ 200mm

c) 300mm

Therefore, 14bars of 200mm c/c spacing is used for main reinforcement

For distributed reinforcement,

Spacing of the bars as per IS456, should be a minimum of

a) 5d = 5x 240 = 1200mm

b) ((Ast)required/(Ast)obtained) x 1000

= ((π/4) x6^2) / 14278.34303) x1000 = 461mm

c) 450mm

Therefore, 24bars of 450mm c/c spacing is used for distributed reinforcement

Step 7: Check for Depth of the Slab

As per IS456,

Mu limit = 0.138fck bd^2

i. For Conventional slab,

Mu limit = 0.138fck bd^2

17.1027 x 10^6 = 0.138 x 25 x 1000 x d^2

d = 70.408mm = 7.04cm<30cm

Hence, OK

ii. For Voided Slab,

Mu limit = 0.138fck bd^2

15.4476 x 10^6 = 0.138 x 25 x 1000 x d^2

d = 66.9146mm = 6.69146cm<30cm

Hence, OK

Step 8: Check for Shear

As per IS456,

Nominal shear stress τv = Vu/bd

Where, Vu = shear force due to design loads = wlx/2

Design shear strength of concrete

τc' = K τc

i. For Conventional slab,

W = 15.5 KN/m^2

Therefore, Vu = (15.5 x 3)/2 = 23.25KN/m

Nominal shear stress τv = 23.25 x 10^3/ (1000 x 300)

= 0.0775N/mm^2

Design shear strength of concrete τc' = K τc

Tc = minimum shear reinforcement = 0.28 as per pg no:73 of IS456 for d=300 or more K= 1.00

Therefore, τc' = K τc = 1.00 x 0.28 = 0.28

τc max for M25 grade of concrete is obtained as per IS456 Table 20

τc max = 3.1

$\tau v < \tau c' < \tau c$ max

$0.0775 < 0.28 < 3.1$

Hence, safe

ii. For Voided Slab,
W = 14 KN/m²

Therefore, Vu = (14 x 3)/2 = 21KN/m

Nominal shear stress $\tau v = 21 \times 10^3 / (1000 \times 300)$

$= 0.0775 N/mm^2$

Design shear strength of concrete $\tau c' = K \tau c$

Tc = minimum shear reinforcement = 0.28 as per pg no:73 of IS456

For d=240; K=?

For d = 225; K = 1.15

d = 250; K= 1.1

for d = 240; K = 1.125

Therefore, $\tau c' = K \tau c = 1.125 \times 0.28 = 0.315$

τc max for M25 grade of concrete is obtained as per IS456 Table 20

$\tau v < \tau c' < \tau c$ max

$0.0875 < 0.315 < 3.1$

Hence, safe

4. MODELING

4.1. Casting of Concrete Specimens:

Casted Cubes and Beams for Compressive and Flexural Strength of Concrete:

Fig -2: Mixng Concrete in Concrete Mixer Equipment

Fig -3: Placing 2% Polypropylene in Water Before Mixing

Fig -4: Casting Cubes

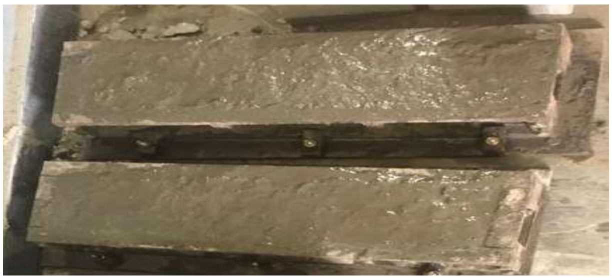

Fig -5: Casting Beams

Fig -6: Placed Under Vibrating Machine to Settle

4.2. Analysis of Slab under ANSYS 16.2:

i. The main focus of proposed work on comparative study of experimentation on voided slab using ANSYS Workbench 16.2. The ANSYS Workbench

16.2 software is observed as effective tool to validate the experimental data.

ii. Three dimensional conventional and voided slabs lightened with polypropylene moulds are modelled in ANSYS WORKBENCH with dimension of (8000x3000x300mm) of conventional slab and (8000x3000x240mm) of voided slab

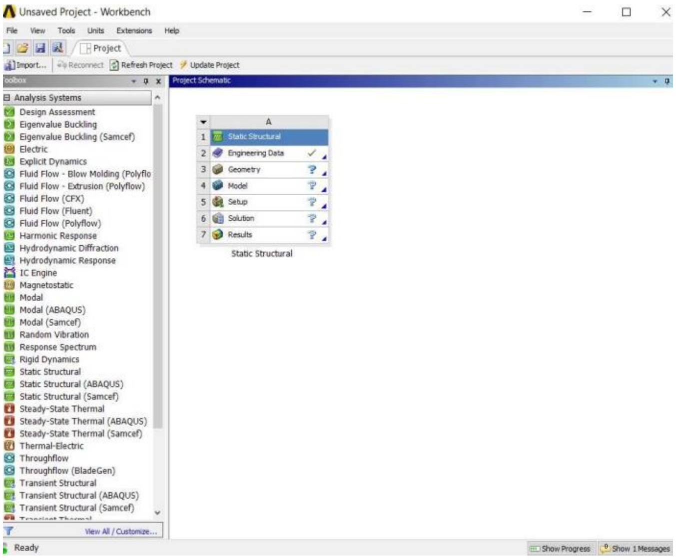

Fig -7: Interface of ANSYS WORKBENCH 16.2 for Static Structural

Step 1: - Engineering Data

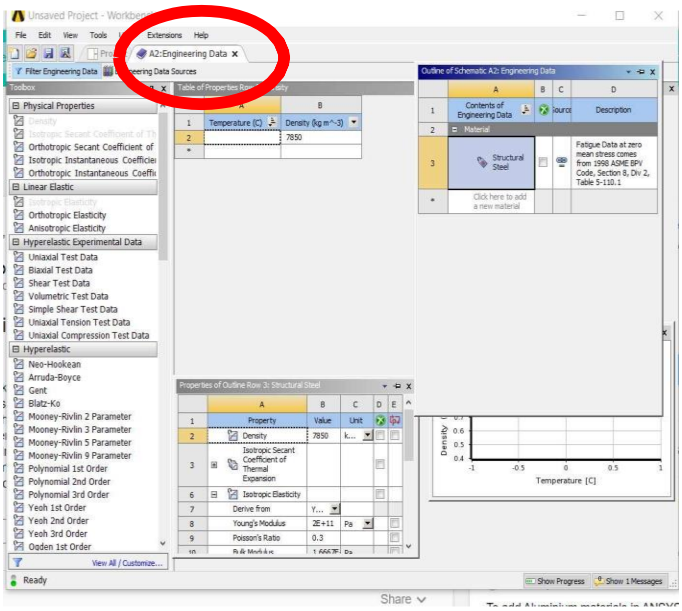

Fig -8: Interface of Engineering Data

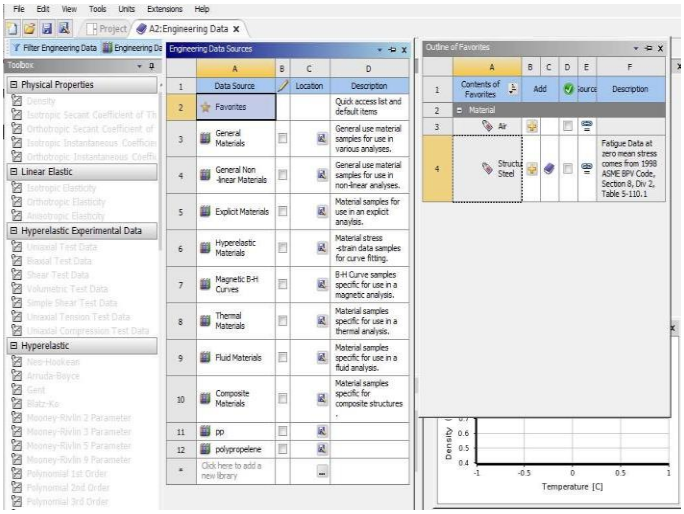

Fig -9: Materials Available

Engineering data helps us to input different materials used in the project, the materials are available as mentioned in the above figure. Some materials which are not updated in the list and is used in the project can be inserted by tapping click here to add a new library and thus input the required material physical properties. Insert polypropylene properties to record and for further use.

Step 2: - Geometry

In geometry by clicking on edit in design modeller we can draw our specifications

For Conventional Slab:

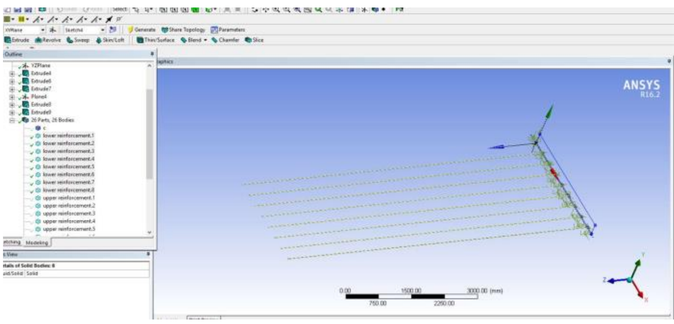

Fig -10: Draw Lower Reinforcement Mentioned as per Methodology Mentioned

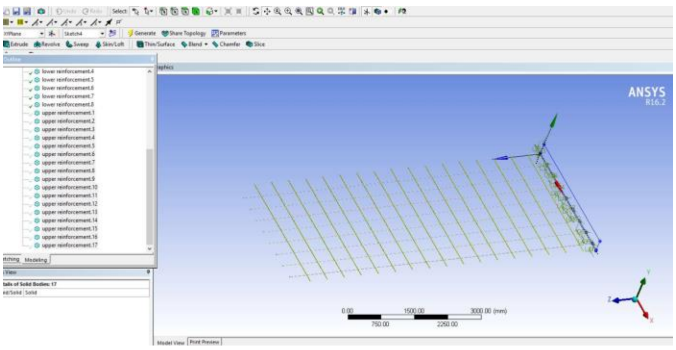

Fig -11: Draw Upper Reinforcement Mentioned as per Methodology Mentioned

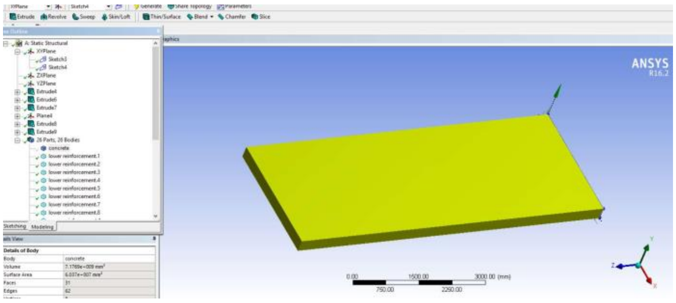

Fig -12: Draw RCC slab as per methodology mentioned(8000x3000x300mm)

For Voided Slab:

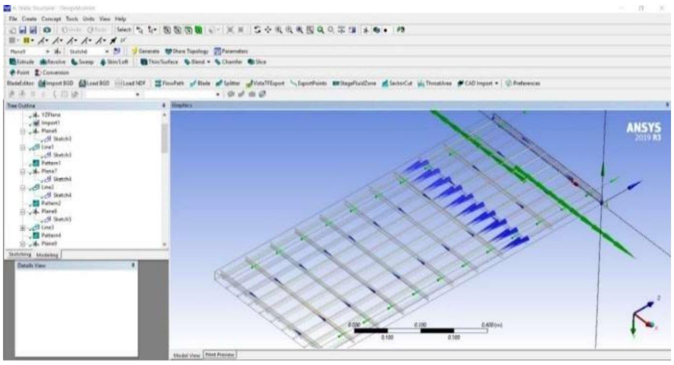

Fig -13: Draw Lower and Upper Reinforcement of Top and Bottom Reinforcement

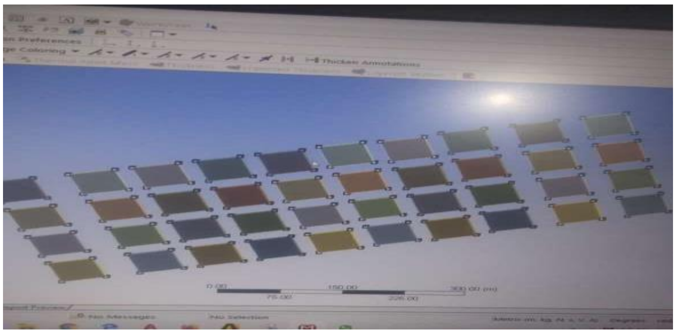

Fig -14: Draw Moulds above Bottom Reinforcement

Step 3: - Model

Right click on model and tap edit in mechanical, An ANSYS mechanical editor will be opened now generate mesh, and add the load or pressure and can go through the solution.

For Conventional Slab:

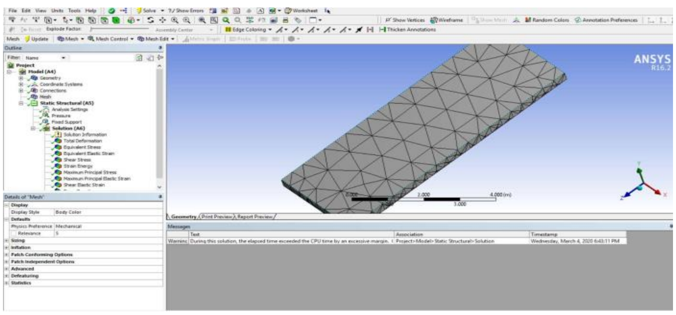

Fig -15: Generating Mesh

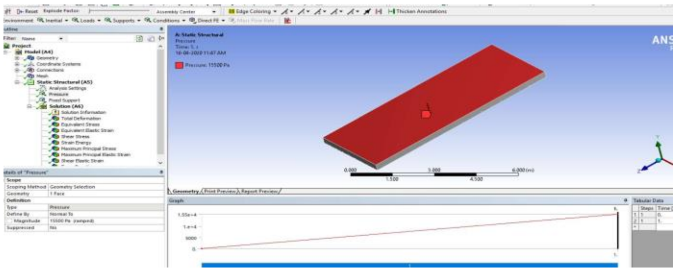

Fig -16: Add load or pressure in Static Structural (15500Pa)

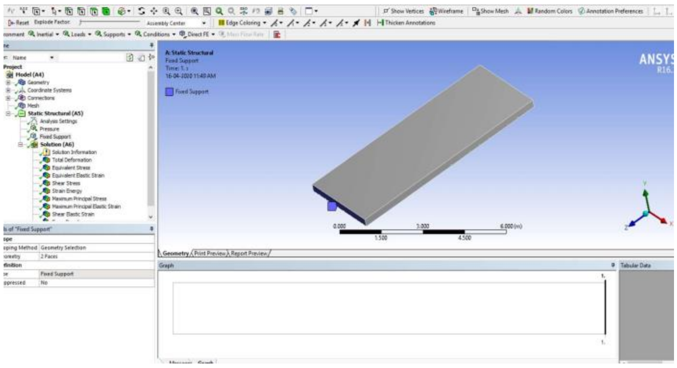

Fig -17: Add Support in Static Structural

For Voided Slab:

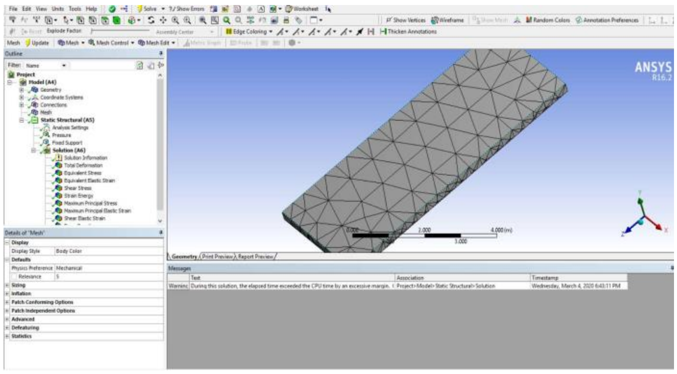

Fig -18: Generating Mesh

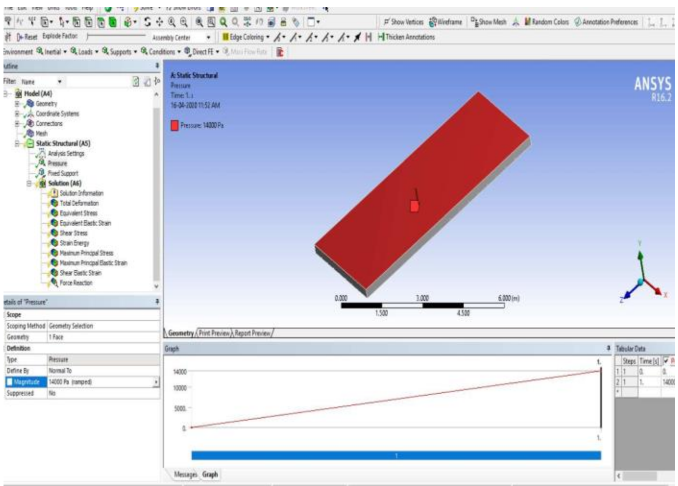

Fig -19: Add load or pressure in Static Structural (15500Pa)

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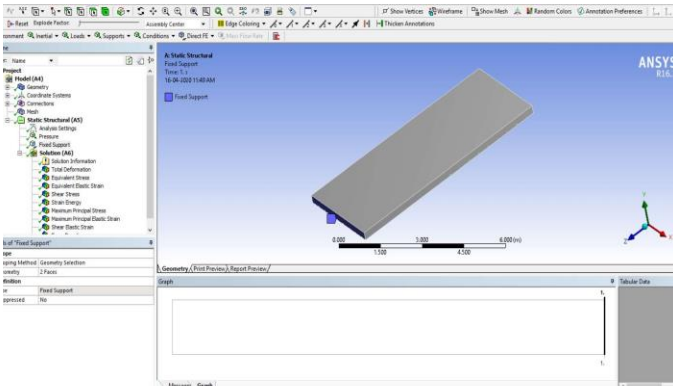

Fig -20: Add Support in Static Structural

5. RESULTS

5.1 Tests Results on Materials:

1. Specific Gravity of Cement:

Laboratory tests results for Specific gravity of cement (OPC)

Observation values

Empty weight of flask with stopper (W1) = 30gm
Weight of flask + Cement (W2) = 46gm
Weight of flask + Cement + Kerosene (W3) = 87gm
Weight of flask + Kerosene (W4) = 76gm
Specific gravity of kerosene = 0.79
Specific gravity of cement = (W2-W1)/ [(W2-W1)- (W3-W4)] x0.79
= (46-30)/ [(46-30) -(87-76)]x0.79
= 3.15

2. Concrete Slump Test for Workability:

The laboratory value of slump obtained = 25mm
Which is a true slump, thus concrete gets evenly slump

3. Specific Gravity of Fine Aggregates:

The Laboratory test values for the specific gravity of sand is shown in below table.

Table -10: Observation values of Specific Gravity Of Sand

Mass of Empty Pycnometer(M_1)	440g
Mass of Empty Pycnometer + Dry soil(M_2)	1800g
Mass of Empty Pycnometer + sample + water(M_3)	2200g
Mass of Pycnometer + Water(M4)	1347g

specific gravity of sand = (M2-M1) /[(M4-M1) – (M3-M2)]

= (1448-439) / [(1257-439) - (1878-1448)]

= 2.601

4. Specific Gravity of Coarse Aggregates:

The Laboratory test values for the specific gravity of coarse aggregate is shown in below table.

Table -11: Observation values of Specific Gravity Of Coarse Aggregate

Mass of Empty Pycnometer(M_1)	439g
Mass of Empty Pycnometer + Dry soil(M_2)	1448g
Mass of Empty Pycnometer + sample + water(M_3)	1878g
Mass of Pycnometer + Water(M4)	1257g

specific gravity of Aggregate = (M2-M1) /[(M4-M1) – (M3-M2)]

= (1800-440)/ [(1347-440) - (2200-1800)] = 2.682

5.2 Tests Results on Concrete Specimen:

1. Compressive Strength of Concrete Specimen:

The test results of Compressive strength of concrete specimen are shown in below table.

Table -12: Observation Table for Compressive Strength of Concrete Specimen

Specimen Name	specimen number& %Fibre added	Load (KN)	Area of Cube (cm^2)	Compressive strength (Kg/cm^2) at 28days of curing
Concrete cube	1 & 0%fibre	510	225	231.05
	2 & 0%fibre	740	225	335.25
	3 & 0%fibre	790	225	357.91
Fibre added concrete cube	1 & 2%fibre	720	225	326.53
	2 & 2%fibre	790	225	357.91
	3 & 2%fibre	760	225	345.61

Average Compressive Strength of Cube,

For Concrete beam = 308.07 Kg/cm^2 = 30.2MPa

For Fibre added beam = 343.35 Kg/cm^2 = 343.35/10.197

= 33.67MPa

Fig -21: Testing of Cube Specimen After Curing

2. Flexural Strength of Concrete Specimen:

The test results of Flexural strength of concrete specimen are shown in below table.

Table -13: Observation Table for Flexural Strength of Concrete Specimen

Specimen Name	Specimen number & fibre added	Load (KN)	Average cracked length(a) Cm	Breadth (b)mm, Depth (d)mm	Flexural Strength N/mm^2 $fc=pl/bd^2$, a>20cm At 28days
Concrete beam	1&0%fibre	17.5	27.3	150	2.07
	2&0%fibre	15	28.8	150	1.77
	3&0%fibre	16.5	27.9	150	1.89
Fibre added beam	1&2%fibre	24.5	26.4	150	2.903
	2&2%fibre	17.5	24.6	150	2.07
	3&2%fibre	21	23.7	150	2.763

Average Flexural Strength of beam,

For Concrete beam = 1.91 N/mm^2

For Fibre added beam = 2.578 N/mm^2

Fig -22: Placing Specimen for Loading

Fig -23: Failure of Specimen After Loading

5.3 Ansys Analysis Results:

For Conventional Slab:

1. Mesh Results:

Table -14: Ansys Table of Statistics for Mesh

Bodies	26
Active Bodies	26
Nodes	1142903
Elements	526401
Mesh Metric	None

2. Total Deformation:

Table -15: Ansys Table of Statistics for Total Deformation

Time[s]	Minimum [m]	Maximum [m]
1	0	2.4303e-3

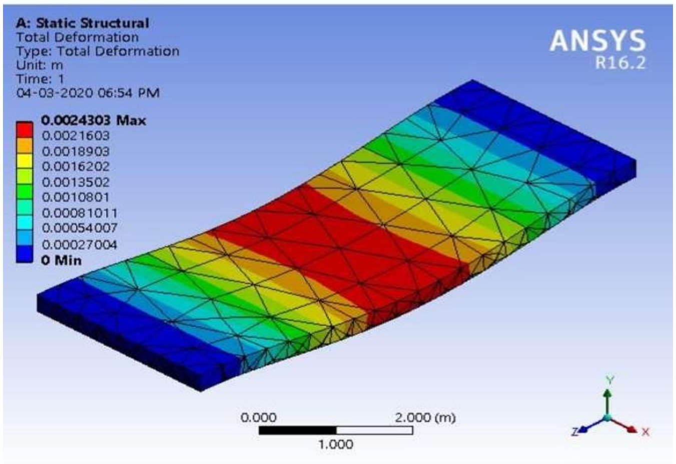

Fig -24: Ansys result for Total Deformation

3. Equivalent Stress:

Table -16: Ansys Table of Statistics for Equivalent Stress

Time[s]	Minimum [Pa]	Maximum [Pa]
1	9475.1	1.0562e+8

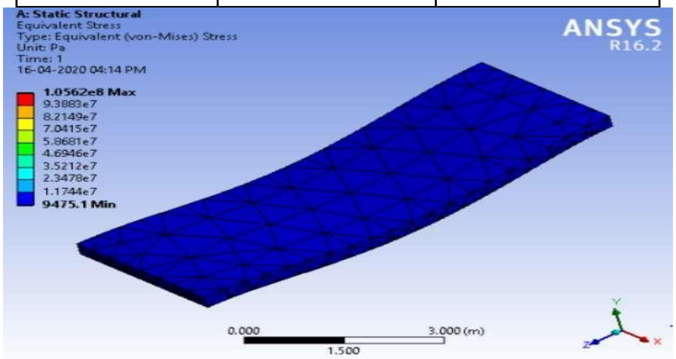

Fig -25: Ansys result for Equivalent Stress

4. Equivalent Elastic Strain:

Table -17: Ansys Table of Statistics for Equivalent Elastic Strain

Time[s]	Minimum [m/m]	Maximum [m/m]
1	6.36e-7	8.4461e-4

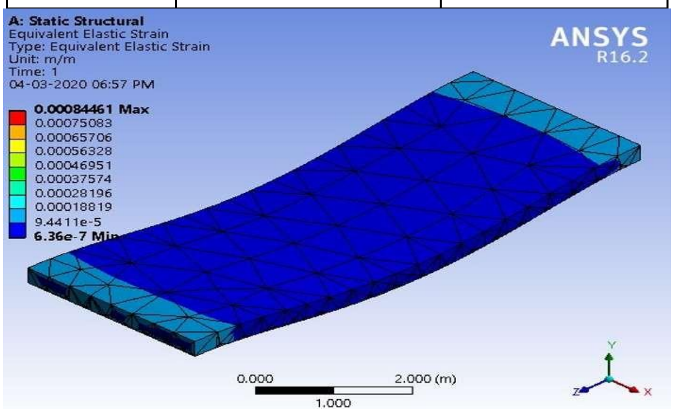

Fig -26: Ansys result for Equivalent Elastic Strain

5. Shear Stress:

Table -18: Ansys Table of Statistics for Shear Stress

Time[s]	Minimum [Pa]	Maximum [Pa]
1	-2.5536e7	1.9067e7

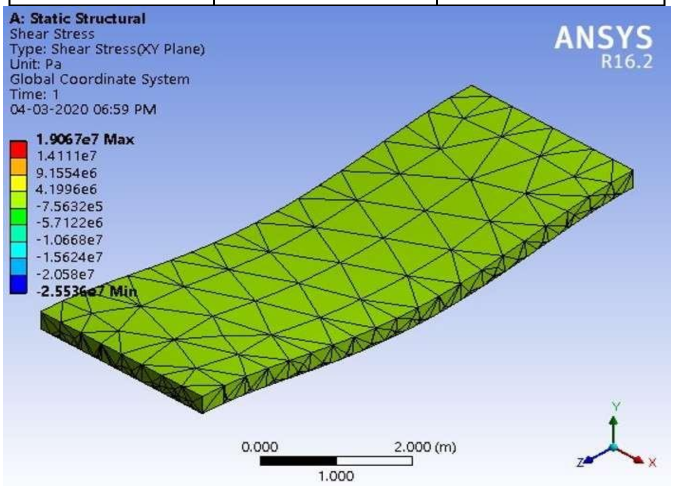

Fig -27: Ansys result for Shear Stress

6. Strain Energy:

Table -19: Ansys Table of Statistics for Strain Energy

Time[s]	Minimum [J]	Maximum [J]
1	6.002e-9	1.3547

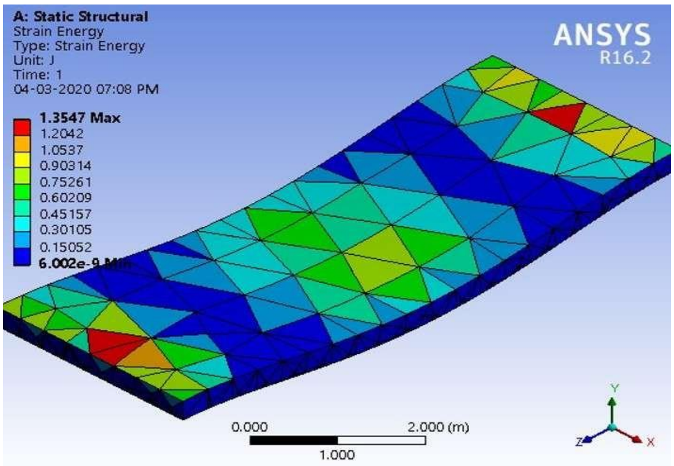

Fig -28: Ansys result for Strain Energy

7. Maximum Principle Stress:

Table -20: Ansys Table of Statistics for Maximum Principle Stress

Time[s]	Minimum [Pa]	Maximum [Pa]
1	-1.2221e+7	1.1654e+8

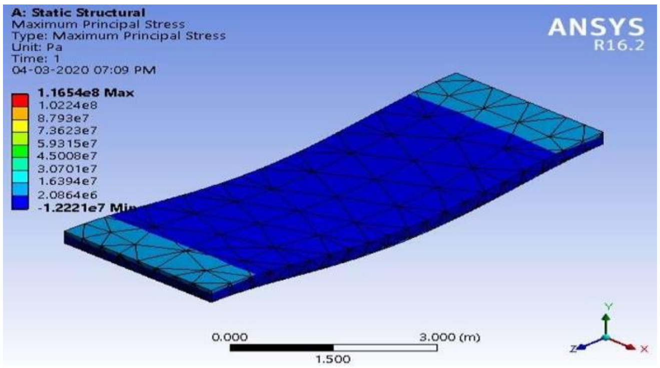

Fig -29: Ansys result for Maximum Principle Stress

8. Maximum Principle Elastic Strain:

Table -21: Ansys Table of Statistics for Maximum Principle Elastic Strain

Time[s]	Minimum [m/m]	Maximum [m/m]
1	-7.348e-6	7.521e-4

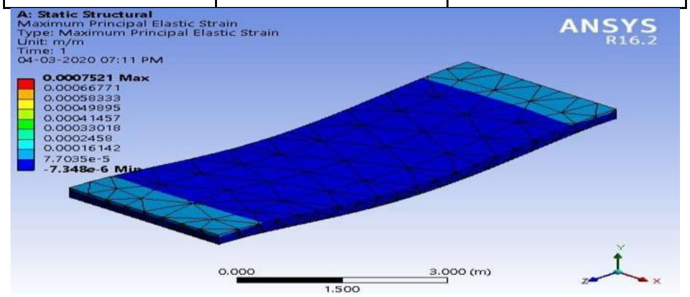

Fig -30: Ansys result for Maximum Principle Elastic Strain

9. Shear Elastic Strain:

Table -22: Ansys Table of Statistics for Shear Elastic Strain

Time[s]	Minimum [m/m]	Maximum [m/m]
1	-3.3196e-4	2.4787e-4

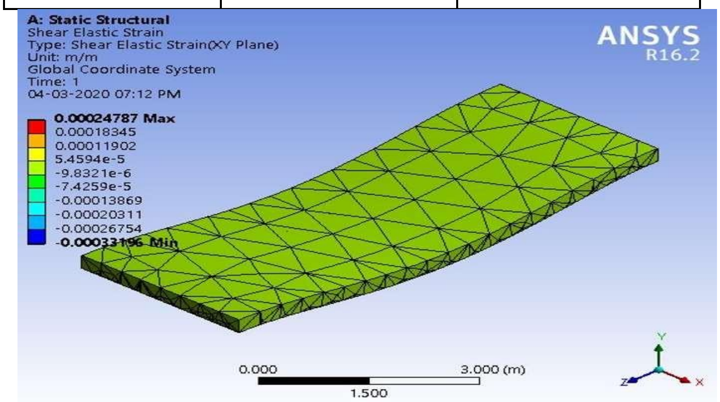

Fig -31: Ansys result for Shear Elastic Strain

10. Force reactions:

Table -23: Ansys Table of Statistics for Force Reactions

Time [s]	Force Reaction(X) [N]	Force Reaction(Y) [N]	Force Reaction(Z) [N]	Force Reaction (Total)[N]
1	2.3856	3.7151e+5	38.681	3.7151e+5

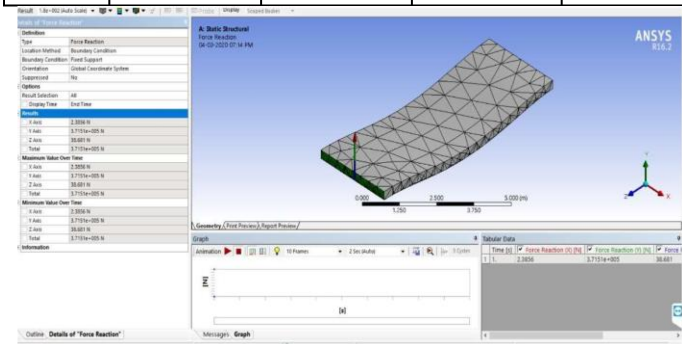

Fig -32: Ansys result for Force Reactions

For Voided Slab:

1. Mesh Results:

Table -24: Ansys Table of Statistics for Mesh

Bodies	40
Active Bodies	40
Nodes	682115
Elements	1057118
Mesh Metric	None

2. Total Deformation:

Table -25: Ansys Table of Statistics for Total Deformation

Time[s]	Minimum [m]	Maximum [m]
1	0	1.7201e-5

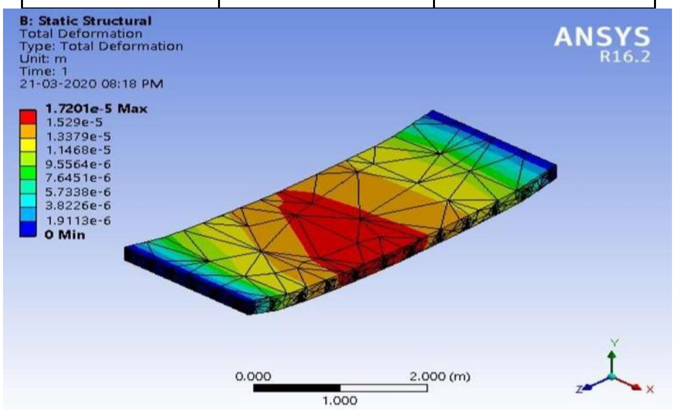

Fig -33: Ansys result for Total Deformation

3. Equivalent Stress:

Table -26: Ansys Table of Statistics for Equivalent Stress

Time[s]	Minimum [Pa]	Maximum [Pa]
1	1128.1	1.1429e+7

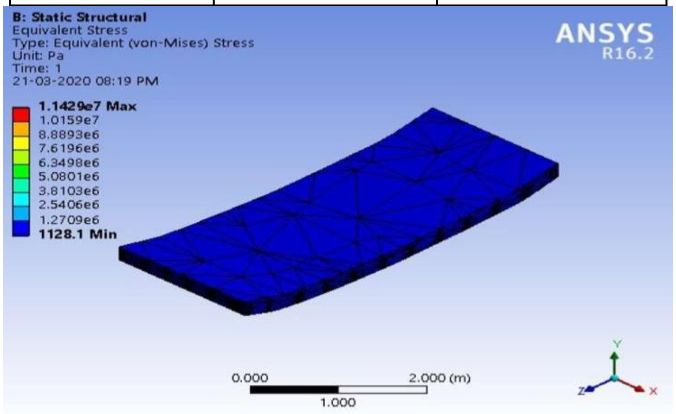

Fig -34: Ansys result for Equivalent Stress

4. Equivalent Elastic Strain:

Table -27: Ansys Table of Statistics for Equivalent Elastic Strain

Time[s]	Minimum [m/m]	Maximum [m/m]
1	4.1001e-8	7.7543e-5

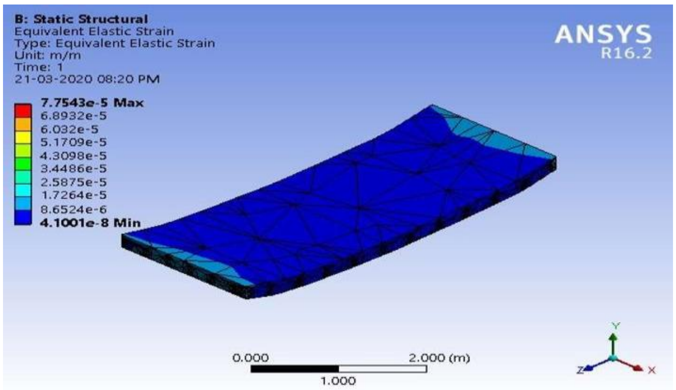

Fig -35: Ansys result for Equivalent Elastic Strain

5. Shear Stress:

Table -28: Ansys Table of Statistics for Shear Stress

Time[s]	Minimum [Pa]	Maximum [Pa]
1	-2.1757e+6	2.2989e+6

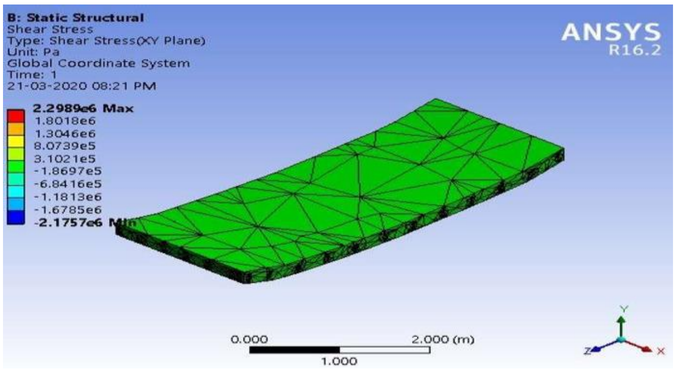

Fig -36: Ansys result for Shear Stress

6. Strain Energy:

Table -29: Ansys Table of Statistics for Strain Energy

Time[s]	Minimum [J]	Maximum [J]
1	2.4392e-13	3.6112e-2

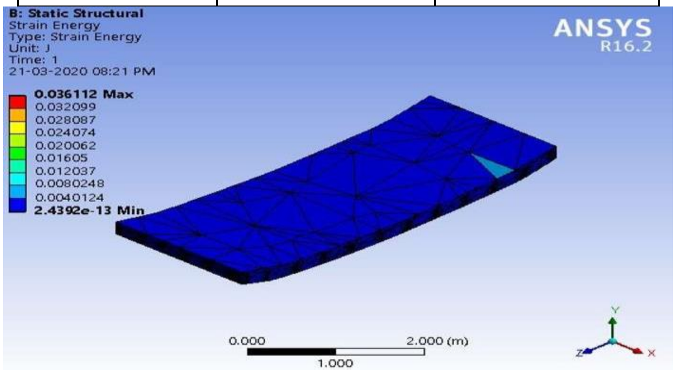

Fig -37: Ansys result for Strain Energy

7. Maximum Principle Stress:

Table -30: Ansys Table of Statistics for Maximum Principle Stress

Time[s]	Minimum [Pa]	Maximum [Pa]
1	-1.2838e+6	9.0359e+6

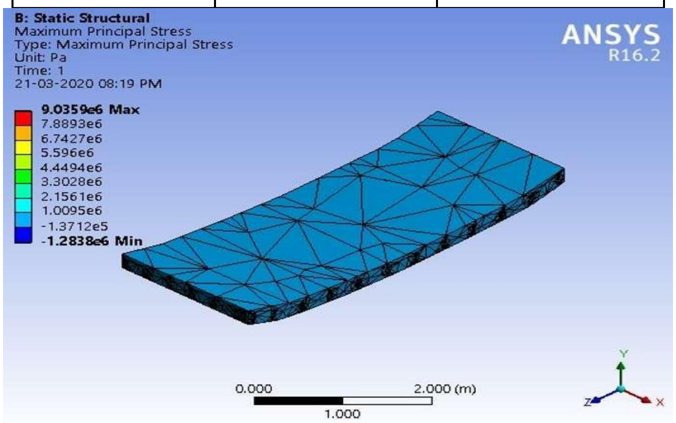

Fig -38: Ansys result for Maximum Principle Stress

8. Maximum Principle Elastic Strain:

Table -31: Ansys Table of Statistics for Maximum Principle Elastic Strain

Time[s]	Minimum [m/m]	Maximum [m/m]
1	4.1001e-8	7.7543e-5

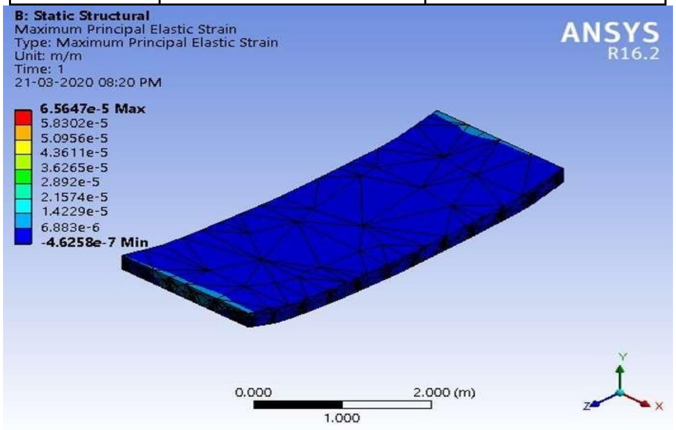

Fig -39: Ansys result for Maximum Principle Elastic Strain

9. Shear Elastic Strain:

Table -32: Ansys Table of Statistics for Shear Elastic Strain

Time[s]	Minimum [m/m]	Maximum [m/m]
1	-2.8284e-5	2.9886e-5

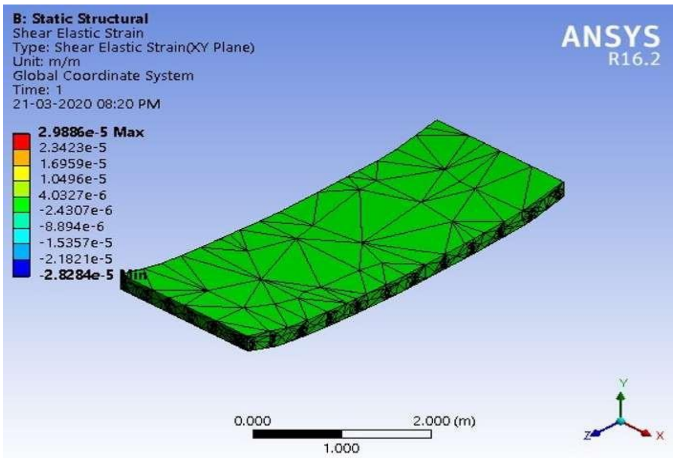

Fig -40: Ansys result for Shear Elastic Strain

10. Force reactions:

Table -33: Ansys Table of Statistics for Force Reactions

Time [s]	Force Reaction(X) [N]	Force Reaction(Y) [N]	Force Reaction(Z) [N]	Force Reaction (Total)[N]
1	-8.1248	1.5499e+5	-3.0826e-5	1.5499e+5

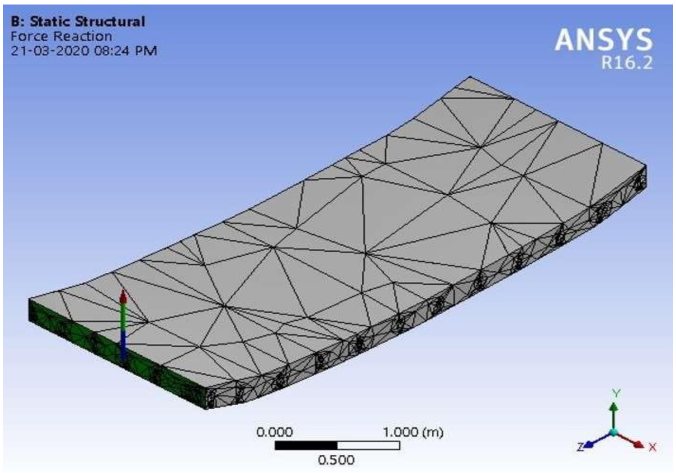

Fig -41: Ansys result for Force Reactions

6. COST ANALYSIS

Table -34: Cost Analysis of both Flat Slab and Voided Slab

	Material	Quantity	Unit price	Total Material price
Flat slab [8x3x 0.3]	Concrete [m³]	11.088	220	2,439.36
	Rebar[m²]	17.923	2,600	46,599.8
	Formwork [m²]	95.1205	52	4,946.26
U-Boot beton slab [8x3x0.2 4m]	Concrete [m³]	8.8704	220	1,951.488
	Rebar[m²]	14.2783	699	9,980.5317
	Formwork [m²]	94.025	52	4,889.3
	U-Boot Betons	58	140	8,120

Total Cost of Conventional Slab= Rs. 53,985.42/-

Total Cost of Voided Slab=Rs. 24,941.3197/-

7. CONCLUSIONS

1) The Average Compressive (33.67>30.2MPa) and Flexural Strength (2.578>1.91MPa) of the Concrete for Fibre added Specimen are higher than the normal conventional concrete specimen's, which indicates that voided slab controls and resist compressive and flexural stresses.
2) The self-weight of the voided slab is reduced by 20%.
3) The Thickness of the slab is also reduced by 20%.
4) The Cost of the Slab is reduced by 56.694%, as quantity of steel and concrete is rapidly decreased.
5) The ANSYS 16.2 Results shows that the voided slab is much better than the conventional or flat slab are discussed below.

i. Total Deformation of Voided slab (1.72x10-5m) < Conventional Slab (2.4x10-3m), Which indicates Voided slab is undergoing less deformation to the conventional slab.
ii. Equivalent Stress of Voided slab (1.142x107Pa) < Conventional Slab (1.0562x108Pa), Which indicates Voided Slab Undergoes Lesser Stress to the conventional slab.
iii. Equivalent Elastic Strain of Voided slab (7.75x10-5m/m) < Conventional Slab (8.446x10-4m/m), Which indicates Voided Slab Undergoes less elastic deformation in response to an applied force to the conventional slab.
iv. Shea Stress of Voided slab (2.2989x106Pa) < Conventional Slab (1.9067x107Pa), Which indicates Voided Slab Undergoes lesser tangential forces to the conventional slab.
v. Strain Energy of Voided slab (3.6112x10-2J) < Conventional Slab (1.3547J), Which indicates Voided Slab Less likely gets Strained to the External imposed loads to the conventional slab.
vi. Maximum Principle Stress of Voided slab (9.0359x106Pa) < Conventional Slab (1.1654x108Pa), Which indicates Voided Slab Undergoes less normal stresses to the conventional slab.
vii. Maximum Principle Elastic Strain of Voided slab (6.5647x10-5m/m) < Conventional Slab (7.521x10-4m/m), Which indicates Voided Slab Undergoes less elastic deformation in response to a normal force to the conventional slab.
viii. Shear Elastic Strain of Voided slab (2.9886x10-5m/m) < Conventional Slab (2.4787x10-4m/m), Which indicates Voided Slab Undergoes less tangential strain to the conventional slab.
ix. Total Force reactions acting on Voided slab (1.5499x105N) < Conventional slab (3.715x105N), Which indicated the voided slab is undergoing less reactional forces to the conventional slab.

8. FUTURE SCOPE

1) U-Boot Beton Technology can also be used in one-way slab system rather than two-way slab system.
2) Used in Parking areas and in Storage godowns as number of columns required are less.
3) Suits best for large span halls and buildings like theatres, auditoriums, seminar halls etc.
4) Suitable for High-Rise buildings.
5) Voided Slab system together with kinematic base isolation system has good seismic performance as in plastic void construction, the voids are made using recycled plastic and the steel is made using recycled steel. If desired, the concrete can even be made using recycled aggregate.
6) As self-weight and load acting on slab is less this type of system is best suitable for mobile homes.

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