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A Study on Flexural Behaviour of Rectangular GPC Slabs with Simply Support using ANSYS Software

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Abstract: Geopolymer concrete is one of the emerging construction materials as a substitute for conventional cement as it eliminates the usage of OPC. An Analytical study has been carried out to investigate flexural behaviour of high strength traditionally vibrated concrete (HSTVC) and high strength Geo polymer concrete (HSGPC) of twelve slabs with all edges were simply supports were analysed using ANSYS Software. Sizes of slabs were 1000X1500X65mm. ANSYS WORKBENCHV16.2 software was used to prepare and analyse non- linear finite element models. Load-deflection behaviour, ultimate load, and load enhancement beyond Johansen's load were obtained and compared with experimental results. ANSYS results demonstrated a sensible concurrence of the test yield. From the analysis results, it was observed that the Ultimate load carrying capacity improved as reinforcement increased. This was consistent in both experimental and ANSYS.
Keywords: HSTVC Slab, HSGPC Slab, ANSYS, Load-deflection behaviour, Non-Linear Analysis, ANSYS WORKBENCHV16.2.

I. INTRODUCTION

Slabs are structural component which can support whole area loadings like dead loads, live loads, floor finishes etc. The behaviour of slabs is mainly governed by edge support condition i.e. simply support, fixed etc. and span length along both shorter and longer directions in multi-floor system. Geopolymer was the name given by Daidovits in 1978 to materials which are characterized by chains or networks or inorganic molecules. Geopolymer cement concrete is made from utilization of by-product materials such as fly ash and ground granulated blast furnace slag (GGBS). Geo Polymer concrete is more ecological. It has good compressive strength comparable to OPC. Since limestone is not present in the mix, corrosion is avoided in rebars. GPC has got good durability properties and thermal stability, less water absorption, very low creep and shrinkage, time of curing and water binder ratio the strength of GPC is controlled.

In this study high strength geo polymer concrete (HS-GPC) and high strength traditionally vibrated concrete (HS-TVC) slabs with simply supports i.e. isolated slabs are analysed using mechanical software called ANSYS WORKBENCHV16.2. The grade of concrete for both slabs are M60. The slabs are analysed to study the flexural behaviour and ultimate strength for both types of slabs and hence analysed results are compared with experimental results. Use of finite element methods to find out the ultimate loads of slabs and deflections of slabs are recent development. Using this software nonlinear analysis can be carried out by defining the nonlinear properties of materials. Studied using ANSYS finite element package has shown that it can be simulate the behaviour of reinforced concrete elements. The results obtained from ANSYS are compare with experimental results.

A. Objectives

1) To model the reinforced concrete slabs called as HSTVC slabs and HSSGPC with different percentage of steel using FEM.
2) To prove the properties of GPC are similar to conventional concrete.
3) To determine analytically the load-deflection behaviour, ultimate load using ANSYS WORKBENCHV16.2 and then determine the load enhancement beyond Johansen's load and load detraction behind Johansen's load for each slabs from results.
4) To study the load-deflection behaviour and strength of GPC slabs and TVC slabs.
5) To compare the results of analytical study with corresponding experimental results.

II. METHODOLOGY FOR FINITE ELEMENT MODELLING AND ANALYSIS USING ANSYS

FEM is process serves as a step--by--step for conducting a Finite Element Analysis (FEA) using ANSYS WorkbenchV16.2. Hence Finite element analysis is used to analyze these structural components. Finite Element Analysis (FEA) is a process used for the evaluation of structures, providing an accurate prediction of the component's response subjected to various loads.

A. *Pre-Processing & Engineering Data*

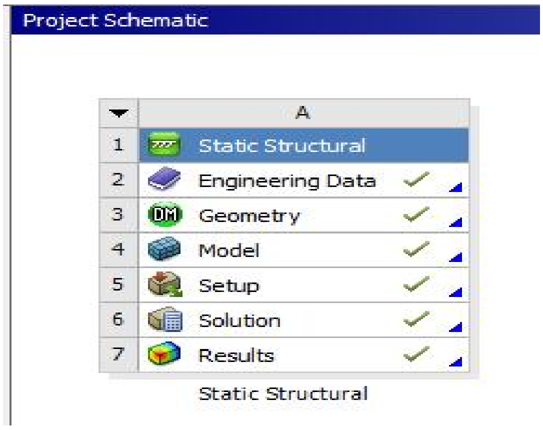

Fig. 1 Step involving in processing of the model and analysis of slab

TABLE 1: Illustrates particulars of compressive strength, Young's modulus, Poisson's ratio and Density obtained from experimentally.

Slab	(fck)(Mpa)	ELASTIC MODULUS Ec=5000fck (Mpa)	POISSON'S RATIO	DENSITY (Kg/m^3)
TVC1	63.43	39821.4766	0.2	2400
TVC2	63.43	39821.4766	0.2	2400
TVC3	63.43	39821.4766	0.2	2400
TVC4	63.43	39821.4766	0.2	2400
TVC5	63.43	39821.4766	0.2	2400
TVC6	63.43	39821.4766	0.2	2400
GPC1	57.09	37778.96	0.16	2700
GPC2	57.09	37778.96	0.16	2700
GPC3	57.09	37778.96	0.16	2700
GPC4	57.09	37778.96	0.16	2700
GPC5	57.09	37778.96	0.16	2700
GPC6	57.09	37778.96	0.16	2700

B. *Geometry and Modelling*

The Finite Element Analysis included modelling of traditionally vibrated concrete and geo polymer concrete slabs

1) *Modeling of Reinforced Concrete and Steel Reinforcement*
   a) Model slab of size 1500mmx100mmx65mm was created in ANSYS using rectangular block.
   b) Structural steel was used to model steel reinforcement in ANSYS. It truly is a 3D line element and having three degrees of freedom at each node.

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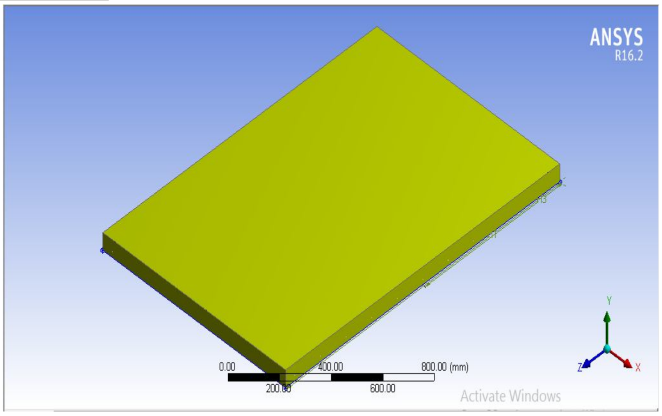

Fig. 2 Concrete model in ANSYS

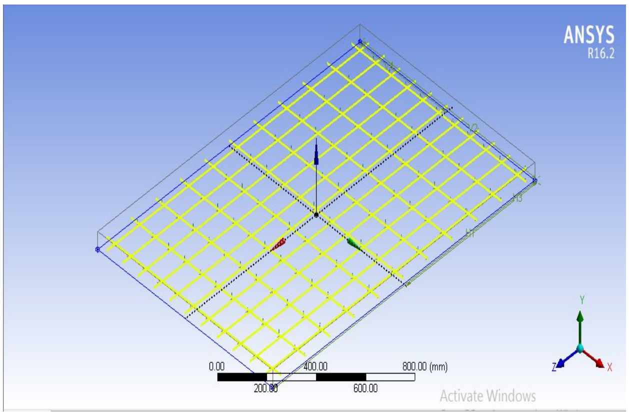

Fig. 3 Concrete model in ANSYS

TABLE 2: Illustrates particulars of geometric details of slab.

Slab	Dimensions of slab in mm	Effective dimensions of slab in mm
TVC-1	1500x1000x65	1400x900x65
TVC-2	1500x1000x65	1400x900x65
TVC-3	1500x1000x65	1400x900x65
TVC-4	1500x1000x65	1400x900x65
TVC-5	1500x1000x65	1400x900x65
TVC-6	1500x1000x65	1400x900x65
GPC-1	1500x1000x65	1400x900x65
GPC-2	1500x1000x65	1400x900x65
GPC-3	1500x1000x65	1400x900x65
GPC-4	1500x1000x65	1400x900x65
GPC-5	1500x1000x65	1400x900x65
GPC-6	1500x1000x65	1400x900x65

TABLE 3: Illustrates particulars reinforcement details of slabs

Slab	Dia of bars, in mm	Spacing of bars in mm	
		Shorter direction	Longer direction
TVC-1	6	150	150
TVC-2	6	120	150
TVC-3	6	100	150
TVC-4	6	85	150
TVC-5	6	75	150
TVC-6	6	50	150
GPC-1	6	150	150
GPC-2	6	120	150
GPC-3	6	100	150
GPC-4	6	85	150
GPC-5	6	75	150
GPC-6	6	50	150

2) *Model:* Assign the properties of materials with respect to their behavior.

C. Connection

The model of slab was done with all corresponding engineering data and with required experimental data then the bond between two materials is taken as "NO SEPARATION".

D. Meshing

To obtain satisfactory results from the Concrete element, a rectangular mesh was considered. Similar to that of ANSYS MAPDL, meshing will discretize the model into elements and nodes that will resemble the geometry.

E. Loading and Boundary Conditions

Displacement boundary conditions are needed to constraint the model to get a unique solution. All slabs were subjected to uniform distributed loading. The loading points in the finite element versions also were precisely at the same locations as in the experimental set up.

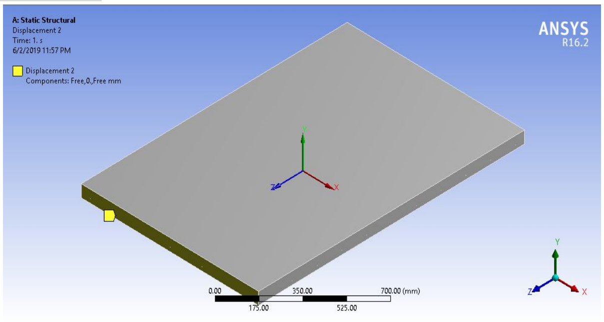
Fig.4: Model with applied boundary conditions

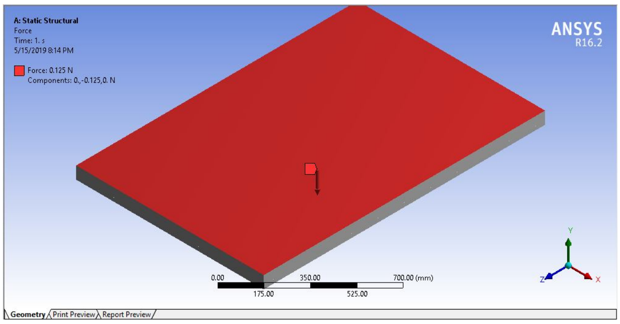
Fig.5: Model with load applied

F. Convergence Criterion

The convergence study was carried out on models to check mesh density. For this a finite element model is to be divided into a number of discrete elements, and the results will converge only if proper number of elements is used. In current study also a convergence study was conducted to determine the mesh density. For the full scale slab of 1500X1000X65 mm the slab. To attain precision in results element size was to be regarded as 20mm or below.

G. Nonlinear Solution in ANSYS

Properties assigned to steel and concrete elements are detailed in above steps. After application of loads at specific locations, the ANSYS programme runs and the results such as deformations of each load step, ultimate load etc. are obtained. Analysis setting in the solution information was such that number of steps the programme has to carry is defined. The time interval for each load step was also defined. The load step definition has no much role in ANSYS workbench. Workbench will consider default settings in the lack of load step definition. When the load steps are offered, the Newton-Raphson solver converges the solution to most exact level. The nonlinear algorithm and nonlinear convergence parameters were defined to obtain precise results.

III. RESULTS AND DISCUSSION

Load Vs deflection behaviour of both high strength traditionally vibrated concrete and high strength geo polymer concrete slabs in analytical studies are compared with experimental results and is tabulated as follows.

TABLE 4: Illustrates particulars reinforcement details of slabs

SLAB	Ultimate load (P_u) (kN)		Deflection (δ_U) (mm)
	Experimental	ANSYS	
TVC1	189	252	34.3
TVC2	156	182	38.16
TVC3	224	275	22.79
TVC4	226	180	18.8
TVC5	218	300	22.06
TVC6	226	165	18.2
GPC1	131.5	165	24.15
GPC2	123	160	22.2
GPC3	163	145	18.9
GPC4	186	235	23.4
GPC5	173	140	19.7
GPC6	201	160	19.26

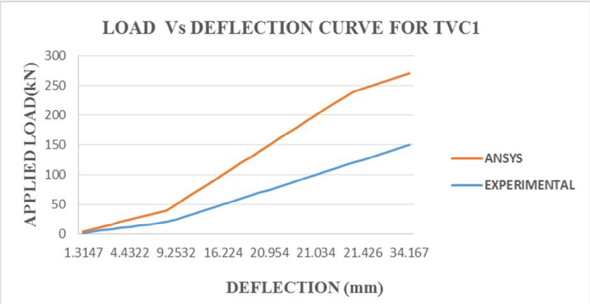

Fig.6 Load- deflection curve for TVC1

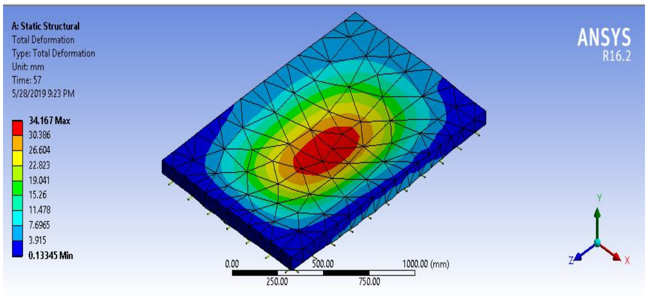

Fig.7 Deflection behaviour of TVC1 at ultimate load

1) ANSYS provided lesser deformation when compared with experimental work under the same loading conditions.
2) The ultimate load carried by analytical model was about 33% higher than experimental values.

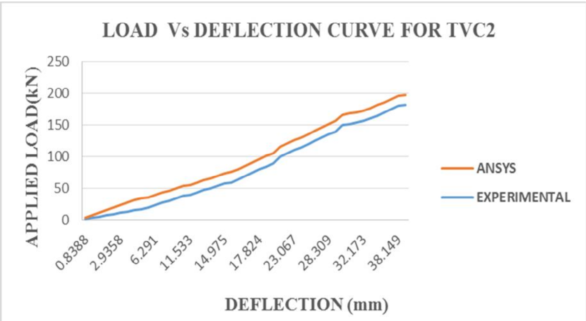

Fig.8 Load- deflection curve for TVC2

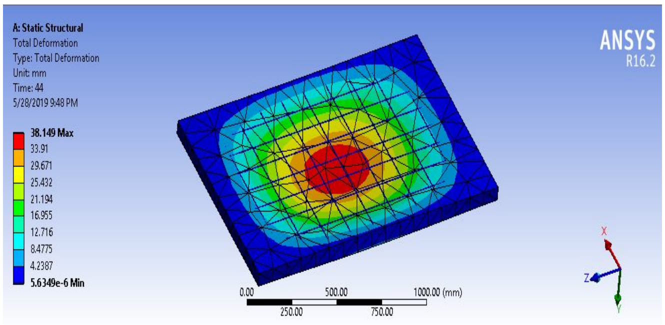

Fig.9 Deflection behaviour of TVC2 at ultimate load

3) The ultimate load carried by analytical model was about 16% higher than experimental values.

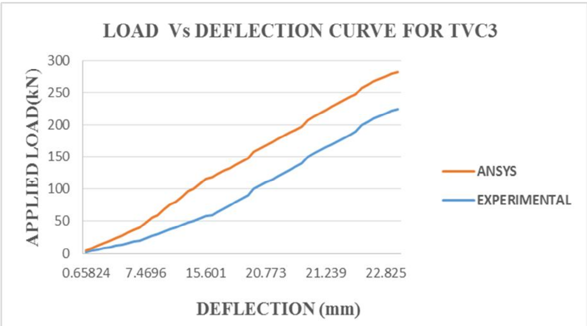

Fig.10 Load- deflection curve for TVC3

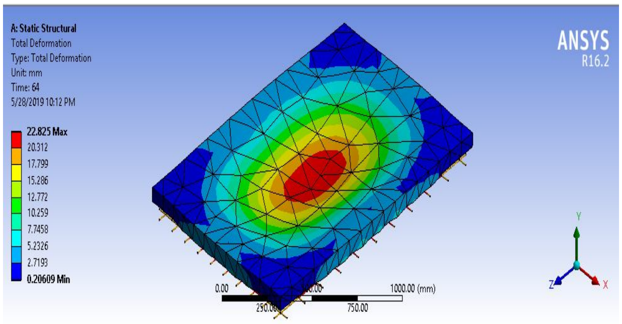

Fig.11 Deflection behaviour of TVC3 at ultimate load

4) The ultimate load carried by analytical model was about 22% higher than experimental values.

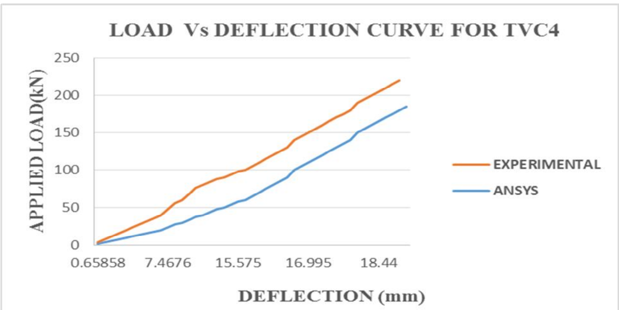

Fig.12 Load- deflection curve for TVC4

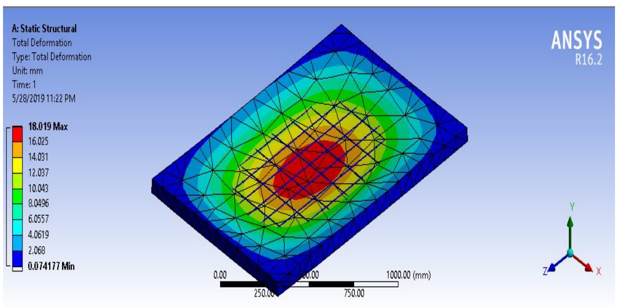

Fig.13 Deflection behaviour of TVC4 at ultimate load

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5) The ultimate load carried by analytical model was about 25% lower than experimental values.
6) The converged solution for the structural element will be realised only when small load steps are given because after initial cracking the ANSYS results will not converge for greater load steps.

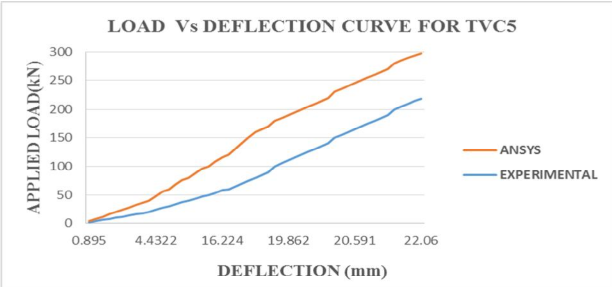


Fig.14 Load- deflection curve for TVC5

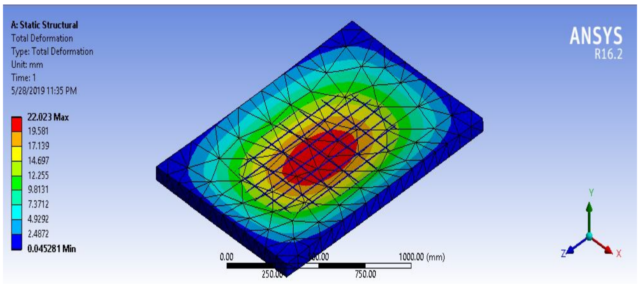


Fig.15 Deflection behaviour of TVC5 at ultimate load

7) The ultimate load carried by analytical model was about 37% higher than experimental values.

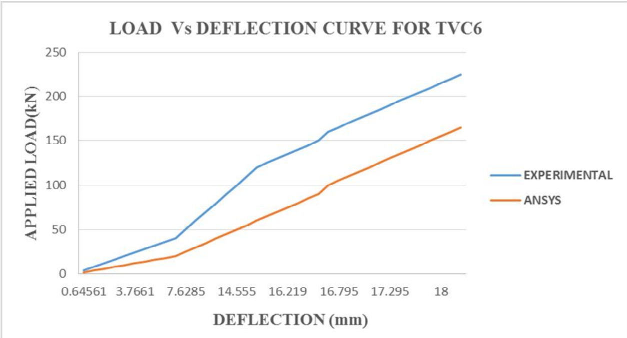


Fig.16 Load- deflection curve for TVC6

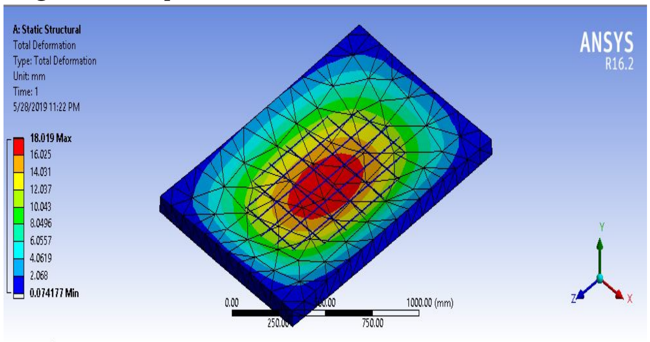


Fig.17 Deflection behaviour of TVC6 at ultimate load

8) The ultimate load carried by analytical model was about 36% lower than experimental values.

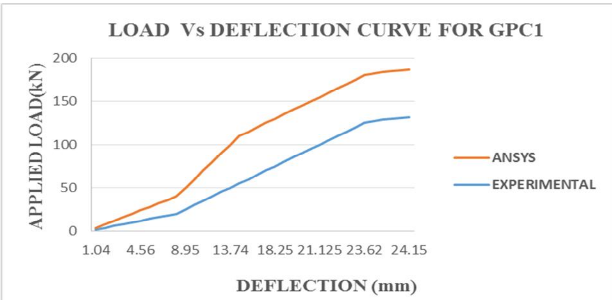


Fig.18 Load- deflection curve for GPC1

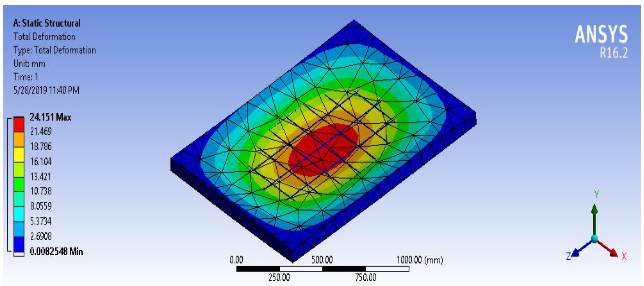


Fig.19 Deflection behaviour of GPC1 at ultimate load

9) The ultimate load carried by analytical model was about 25% higher than experimental values.

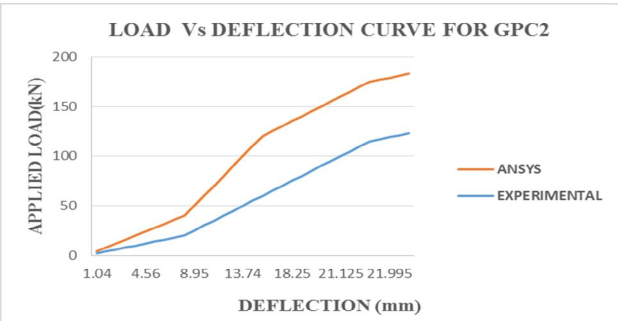


Fig.20 Load- deflection curve for GPC2

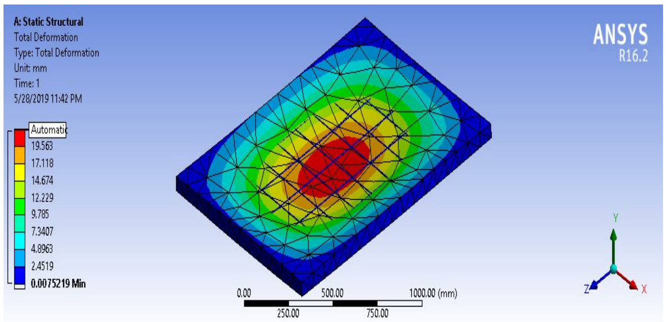
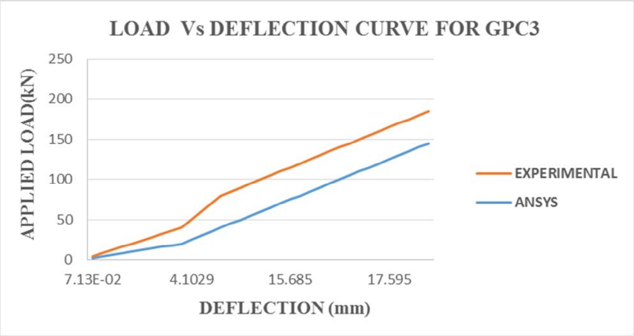


Fig.21 Deflection behaviour of GPC2 at ultimate load

10) The ultimate load carried by analytical model was about 32% higher than experimental values



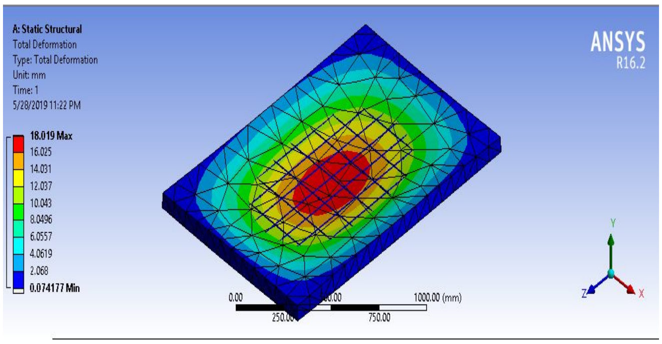
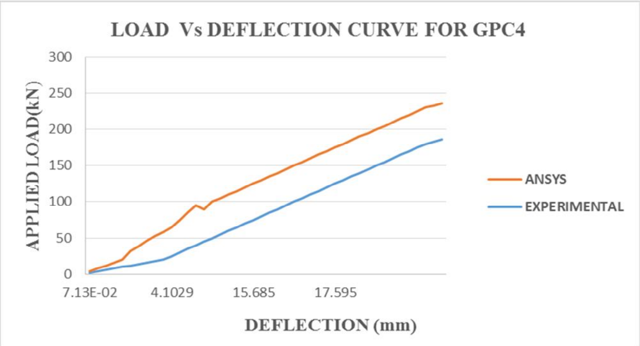


Fig.20 Load- deflection curve for GPC3 Fig.21 Deflection behaviour of GPC3 at ultimate load

11) The ultimate load carried by analytical model was about 12% lower than experimental values.



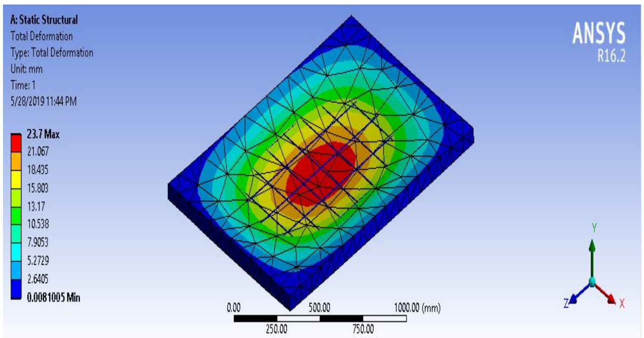
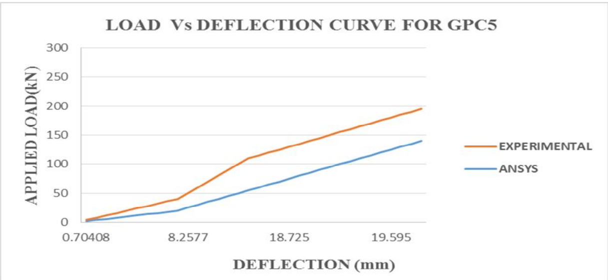


Fig.22 Load- deflection curve for GPC4 Fig.23 Deflection behaviour of GPC4 at ultimate load

12) The ultimate load carried by analytical model was about 26% higher than experimental values.



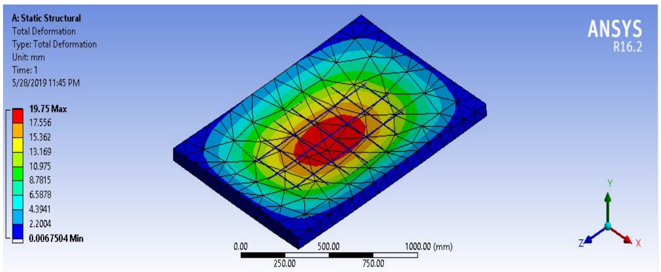
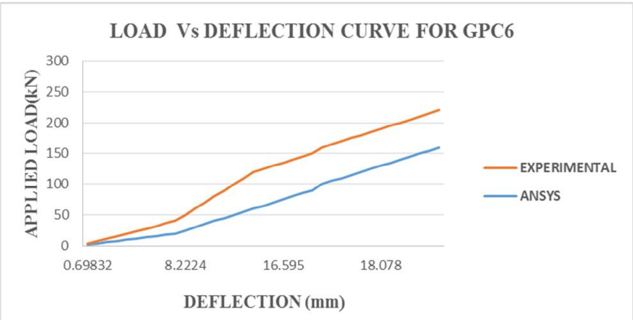


Fig.24 Load- deflection curve for GPC5 Fig.25 Deflection behaviour of GPC5 at ultimate load

13) The ultimate load carried by analytical model was about 23% lower than experimental values.



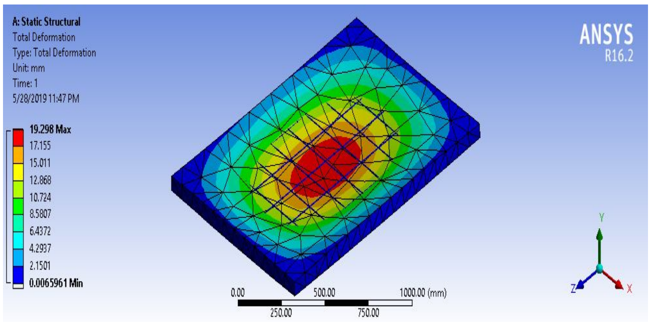


Fig.26 Load- deflection curve for GPC6 Fig.27 Deflection behaviour of GPC6 at ultimate load

14) The ultimate load carried by analytical model was about 25% lower than experimental values.

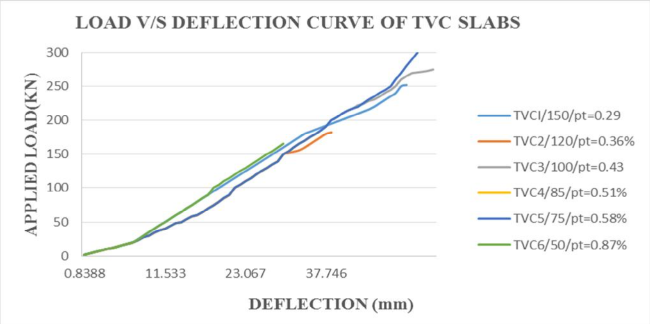


Fig.28 Load- deflection curve for TVC slabs

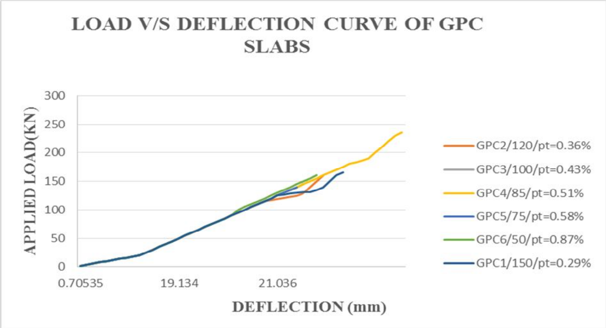


Fig.29 Load- deflection curve for GPC slabs

IV. PERCENTAGE OF STEEL vs ULTIMATE LOAD

TABLE 5: Percentage of steel vs ultimate load relation for TVC and GPC slabs

Percentage of steel	Slab	Ultimate load(KN)		EXP/AN
		Experimental (EXP)	ANSYS (AN)	
0.29	TVC1	189	252	1.33
0.36	TVC2	156	182	1.16
0.43	TVC3	224	275	1.23
0.51	TVC4	226	180	0.79
0.58	TVC5	218	300	1.38
0.87	TVC6	226	165	0.73

Percentage of steel	Slab	Ultimate load(KN)		EXP/AN
		Experimental (EXP)	ANSYS (AN)	
0.29	GPC1	131.5	165	1.25
0.36	GPC2	123	160	1.3
0.43	GPC3	163	145	0.9
0.51	GPC4	186	235	1.26
0.58	GPC5	173	140	0.80
0.87	GPC6	201	160	0.80

15) It is seen that in this case also when percentage of steel increased, ultimate load carrying capacity also increased for both experimental and ANSYS results but as in case of TVC4 and TVC6 slabs percentage of steel increased, ultimate load carrying capacity decreased in ANSYS results when compared with experimental results.

16) It is seen that in this case also when percentage of steel increased, ultimate load carrying capacity also increased for both experimental and ANSYS results but as in case of GPC3, GPC5 and GPC6 slabs percentage of steel increased, ultimate load carrying capacity decreased in ANSYS results when compared with experimental results.

V. COMPARISION OF LOAD ENHANCEMENT AND LOAD DETRACTION

The load enhancement and load detraction of Johansen's yield line load is computed for both experimental and ANSYS cases.

Percentage of steel	Slab	Johansen's Load, P_j (KN)	Ultimate load(KN)		Load enhancement and detraction $L=[P_U-P_j]*100/P_j$	
			Experimental	ANSYS	Experimental	ANSYS
0.29	TVC1	94.23	189	252	100%	167.43%
0.36	TVC2	108.67	156	182	43.55%	67.48%
0.43	TVC3	124.25	224	275	80%	121.32%
0.51	TVC4	135.95	226	180	66.23%	32.40%
0.58	TVC5	148.75	218	300	46.55%	101.68%
0.87	TVC6	197.08	226	165	14.67%	16.27%

Fig.30 Load enhancement and load detraction for TVC slabs

Percentage of steel	Slab	Johansen's Load, P_j (KN)	Ultimate load(KN)		Load enhancement and detraction $L=[P_U-P_j]*100/P_j$	
			Experimental	ANSYS	Experimental	ANSYS
0.29	GPC1	94.23	131.5	165	40%	75%
0.36	GPC2	108.67	123	160	13.18%	47.23%
0.43	GPC3	124.25	163	145	31.18%	16.7%
0.51	GPC4	135.95	186	235	36.81%	72.85%
0.58	GPC5	148.75	173	140	16.30%	5.88%
0.87	GPC6	197.08	201	160	1.98%	18.8%

Fig.31 Load enhancement and load detraction for TVC slabs

17) It can be observed from the above table that load enhancement beyond Johansen's Load was magnifying as the percentage of steel increased. This phenomenon observed in both experimental and ANSYS results for both types of slabs. But it can also be observed from the above table that load detraction behind Johansen's Load was reduce as the percentage of steel increased. This phenomenon observed in TVC6 slabs in ANSYS results.

18) It can be observed from the above table that load enhancement beyond Johansen's Load was magnifying as the percentage of steel increased. This phenomenon observed in both experimental and ANSYS results for both types of slabs. But it can also be observed from the above table that load detraction behind Johansen's Load was reduce as the percentage of steel increased. This phenomenon observed in GPC5 and GPC6 slabs in ANSYS results.

VI. CONCLUSIONS

From the analytical results of HSTVC and HSGPC Slabs are compared with experimental results it can be conclude that,

A. The ultimate loads obtained from ANSYS model for TVC slabs were varied from 16% to 37% higher than the experimental work. And for GPC slabs it was varied from 25% to 36% higher than experimental work. This may be attributed to the assumptions of perfect bond between the reinforcement and concrete in ANSYS model.

B. It can be concluded that up to 30% of ultimate load the behaviour was linear and later nonlinear behaviour is observed due to reduced stiffness.

C. The midspan deflections obtained from ANSYS have been lesser than that of experimental work for same magnitude of load. This may be due to the bond slip between the steel and concrete is disregarded in ANSYS.

D. Deflection decreased as the percentage of reinforcement increased when compared to experimentally obtained result. In some slabs it showed increase in deflection.

E. Ultimate load carrying capacity improved as reinforcement increased. This was consistent in both experimental and ANSYS as it is a expected behaviour of structural members. But in ANSYS it showed decreased load carrying capacity.

F. Load enhancement beyond Johansen's yield line load was decreasing as percentage of reinforcement increased due to more load steps. This is due to the fact that stiffness of the member reduces after the cracking loads till ultimate load.

G. The converged solution for the structural element will be realised only when small load steps are given because after initial cracking, the ANSYS results will not converge for greater load steps.

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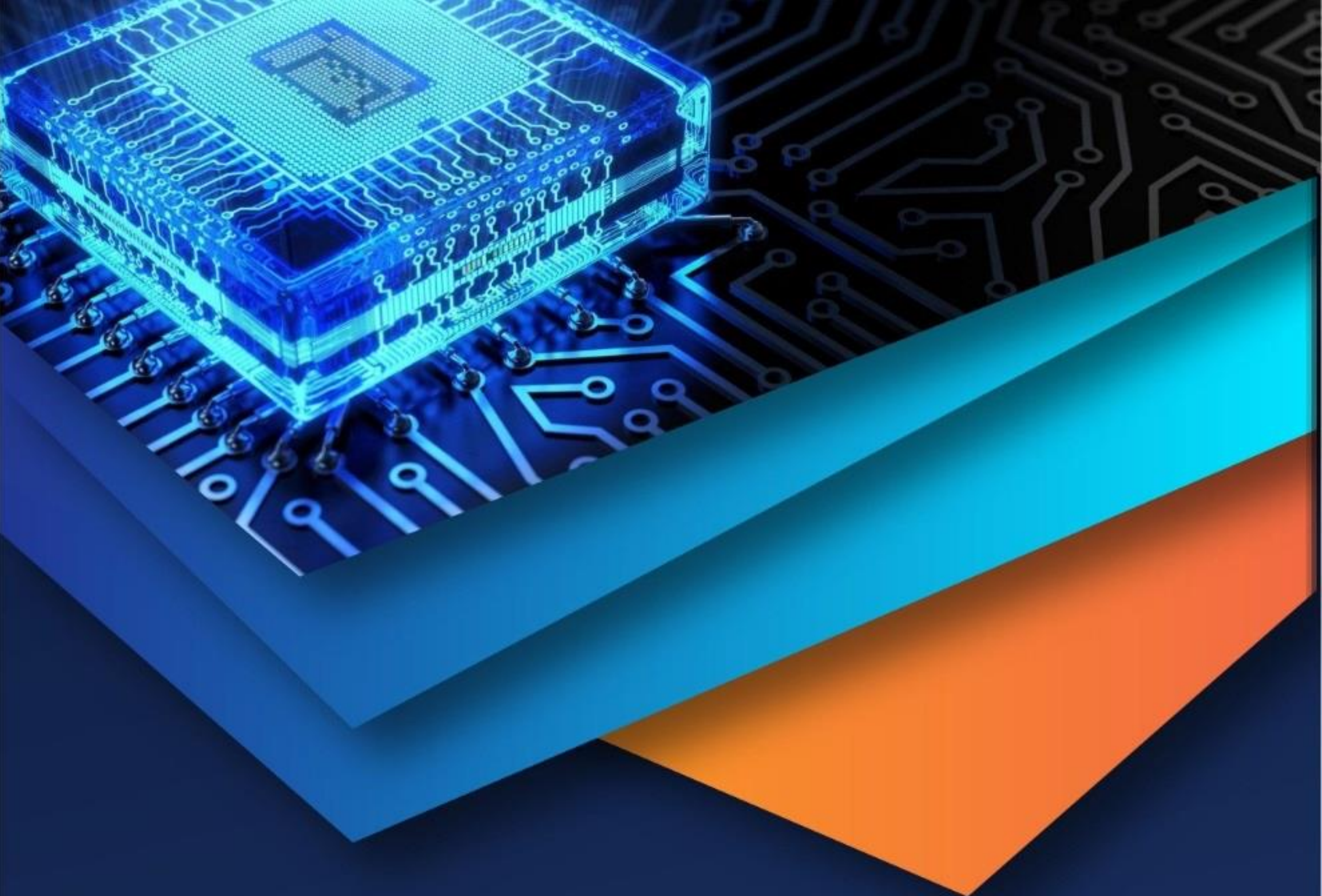

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