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GEOPOLYMER CONCRETE BEAM ANALYSIS BY ANSYS SOFTWARE

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Abstract: Concrete, artificial engineering material made from a mixture of Portland cement, water, fine and coarse aggregates and a small amount of air. It is the most widely used construction material in the world. Concrete is the only major building material that can be delivered to the job site in a plastic state. This unique quality makes concrete desirable as a building material because it can be molded to virtually to any form or a shape. Concrete provides wide latitude in surface textures and colors and can be used to construct a wide variety of structures such as highways and streets, bridges, dams, large buildings, airport runways, irrigation structure, break waters, piers and docks, sidewalks, soils and farm building homes and even barges and ship. Other desirable qualities of concrete as a building material are its strength, economy and durability. Depending on the mixture of materials used, concrete will support, in compression, 700 or more kg/sq cm, (10,000 or more 1b/sq cm) ANSYS, Analyzing Software, has been used in this project. ANSYS Mechanical software is a comprehensive FE analysis (finite element) tool for structural analysis, including linear, nonlinear and dynamic studies. The engineering simulation product provides a complete set of elements behavior, material models and equation solvers for a wide range of mechanical design problems. In addition, ANSYS Mechanical offers thermal analysis and coupled-physics capabilities involving acoustic, piezoelectric, thermal–structural and thermo-electric analysis. The ANSYS Mechanical software suite is trusted by organizations around the world to rapidly solve complex structural problems with ease. Structural mechanics solutions from ANSYS provide the ability to simulate every structural aspect of a product, including nonlinear static analysis that provides stresses & deformations, modal analysis that determines vibration, The M60 grade is used in this paper with different water/binder ratio , 0.3 for GPC(Geopolymer concrete) and 0.3 for OPC(Orginary portland concrete) .

I. INTRODUCTION

In Today’s world, where time is very influential in project planning and iterative calculations. Prototype experiments charges time, money, accuracy and effort of many intellectuals. Simulations or computer aided design comes in to sort these thing up. ANSYS is one those tools which are currently used with a lot of applications which have significant impacts on our daily life. Founded in 1970 by Dr. John A. Swanson as Swanson Analysis Systems, Inc (SASI). Its primary purpose was to develop and market finite element analysis software for structural physics that could simulate :

- Static (stationary)
- Dynamic (moving)
- Thermal (heat transfer) problems.

SASI developed its business in parallel with the growth in computer technology and engineering needs. The company grew by 10 percent to 20 percent each year, and in 1994 it was sold to TA Associates. The new owners took SASI’s leading software, called ANSYS, as their flagship product and designated ANSYS, Inc. as the new company name. Ansys (Analysis System) is a brilliant software used for very complex and crucial analysis which are playing vital roles in today’s engineering.

Basically it is an engineering simulation software. This special software has no parallel application that could stand beside it. ANSYS has two major dimensions.

Simulation Technology:

- Structural Mechanics
- Multiphysics
- Fluid Dynamics
- Explicit Dynamics
- Electromagnetics
- Hydrodynamics (AQWA).

Work flow Technology:

- ANSYS Workbench Platform
- High-Performance Computing
- Geometry Interfaces
- Simulation Process & Data Management.

Mainly they will be related to structural analysis, thermal analysis, problems related to computational fluid dynamics (CFD) and coupling of above mentioned modules.

Since the beginning of the industrial revolution in 1760 there has been an increase in the use of fossil fuel energy resulting in amplified emissions of GHGs (Greenhouse Gases) (Slanina, 2004). This increased global dependency on oil, coal and natural gas has resulted in the release in excess of 1100 Gt (Giga tonne) of CO_2e emissions to the atmosphere (IPCC, 2001). The release of GHGs contributes to anthropogenic induced global warming with the most significant of these gases being CO_2 (Carbon dioxide) (IPCC, 2001). This is due to the sheer quantities that are being emitted, even though it does not have the highest radioactive forcing potential. The cement industry is energy intensive and accounts for a significant portion of these anthropogenic GHG emissions.

Concrete is also the basis of a large commercial industry. Globally, the ready-mix concrete industry, the largest segment of the concrete market, is projected to exceed $100 billion in revenue by 2017. In the United States alone, concrete production is a $30-billion-per-year industry, considering only the value of the ready-mixed concrete sold each year. Given the size of the concrete industry, and the fundamental way concrete is used to shape the infrastructure of the modern world, it is difficult to overstate the role this material plays today.

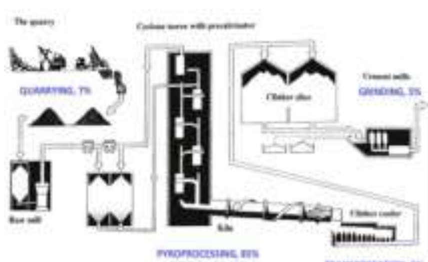

Figure 1: Projecting the growth of ghg's: co_2 emissions from cement industry

Since the beginning of the industrial revolution in 1760 there has been an increase in the use of fossil fuel energy resulting in amplified emissions of GHG's (Greenhouse Gases) (Slanina, 2004). This increased global dependency on oil, coal and natural gas has resulted in the release in excess of 1100 Gt (Giga tonne) of CO_2e emissions to the atmosphere (IPCC, 2001). The release of GHGs contributes to anthropogenic induced global warming with the most significant of these gases being CO_2 (Carbon dioxide) (IPCC, 2001). This is due to the sheer quantities that are being emitted, even though it does not have the highest radioactive forcing potential. The cement industry is energy intensive and accounts for a significant portion of these anthropogenic GHG emissions.

Globally the cement industry contributes between five and eight percent of all CO_2e (Carbon dioxide equivalent) emissions (CIF, 2003; Flower and Sanjayan, 2007; Ulm, 2007). World production totalled 42 billion tonnes in 2013 with the three major global contributors being China accounting for 11 billion tonnes (46 percent), USA accounting for 6 billion tonnes (16 percent) and India accounting for 2.6 billion tonnes (six percent) (USDoI, 2013).

A major producer of CO_2 is the cement industry. It is estimated that the cement activity contributes five to eight percent of global anthropogenic CO_2 emissions. Cement is only a constituent of concrete and accounts for 15 to 30 percent of the world's GHG's.

Concrete is the most commonly used construction material in the world because of its outstanding strength, durability, and availability. In fact, concrete is the world's most consumed man-made material and its use is expected to increase substantially.

From the above discussions it is been clear that the concrete industry producing vast amount of CO_2 around the world and production of concrete is not environmentally friendly, so there is emergency to reduce the usage of cement and this can be achieved by different alternatives

The manufacture of Portland cement clinker involves the calcinations of calcium carbonate according to the reactions:

$$3CaCO_3 + SiO_2 \rightarrow Ca_3SiO_5 + 3CO$$
$$2CaCO_3 + SiO_2 \rightarrow Ca_2SiO_4 + 2CO_2$$

In order to reduce further the CO_2 emissions associated with concrete further viable alternatives to replace OPC are being examined with geopolymer materials considered to be one such alternative.

GEOPOLYMER CONCRETE

In the context of increased awareness regarding the ill-effects of the over exploitation of natural resources, eco-friendly technologies are to be developed for effective management of these resources. Construction industry is one of the major users of the natural resources like cement, sand, rocks, clays and other soils. The ever increasing unit cost of the usual ingredients of concrete have forced the construction engineer to think of ways and means of reducing the unit const of its production. At the same time, increased industrial activity in the core sectors like energy, steel and transportation has been responsible for the production of large amounts like fly ash, blast furnace slag, silica fume and quarry dust with consequent disposal problem.

Concrete under uni-axial tension the stress–strain response follows a linear elastic relationship until the value of the failure stress is reached. The failure stress corresponds to the onset of micro-cracking in the concrete material. The elastic parameters required to establish the relation are elastic modulus (Ec), and tensile strength, (fct). The compressive strength was in the experimental work measured to be 60 MPa. The density of OPC is taken as 24 kN/m^3&in the csse of GPC is 24.2kN/m^3 for plain cement concrete beam respectively.

II. INTRODUCTION TO ANSYS

ANSYS, Inc. is an American Computer-aided engineering software developer headquartered south of Pittsburgh in Cecil Township, Pennsylvania, United States. Ansys publishes engineering analysis software across a range of disciplines including finite element analysis, structural analysis, computational fluid dynamics, explicit and implicit methods, and heat transfer. ANSYS Mechanical is a finite element analysis tool for structural analysis, including linear, nonlinear and dynamic studies. This computer simulation product provides finite elements to model behavior, and supports material models and equation solvers for a wide range of mechanical design problems.

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material models and equation solvers for a wide range of mechanical design problems. In addition, ANSYS Mechanical offers thermal analysis and coupled-physics capabilities involving acoustic, piezoelectric, thermal–structural and thermo-electric analysis. The ANSYS Mechanical software suite is trusted by organizations around the world to rapidly solve complex structural problems with ease. Structural mechanics solutions from ANSYS provide the ability to simulate every structural aspect of a product, including nonlinear static analysis that provides stresses & deformations, modal analysis that determines vibration.

ANSYS is a general purpose finite element modeling package for numerically solving a wide variety of mechanical problems. These problems include: static/dynamic structural analysis (both linear and non-linear), heat transfer and fluid problems, as well as acoustic and electro-magnetic problems.

In general, a finite element solution may be broken into the following three stages. This is a general guideline that can be used for setting up any finite element analysis.

1. **Preprocessing: defining the problem**; the major steps in preprocessing are given below:
    - Define keypoints/lines/areas/volumes
    - Define element type and material/geometric properties
    - Mesh lines/areas/volumes as required

The amount of detail required will depend on the dimensionality of the analysis (i.e. 1D, 2D, axi-symmetric, 3D).

2. **Solution: assigning loads, constraints and solving**; here we specify the loads (point or pressure), contraints (translational and rotational) and finally solve the resulting set of equations.
3. **Postprocessing: further processing and viewing of the results;** in this stage one may wish to see:
    - Lists of nodal displacements
    - Element forces and moments
    - Deflection plots
    - Stress contour diagrams

III. LITERATURE REVIEW

This chapter presents a review of recent research on geopolymers and geopolymer concrete, with an emphasis on low calcium fly ash-based geopolymer paste and concrete. New building materials that enhance both greenness and durability could reduce long-term costs by eliminating the need for the replacement of non-obsolescent structures and thereby reduce the environmental impact. In this connection, geopolymers promise to have a great potential for greenness and durability.

Literature Review On Mix Design and ANSYS:

Balaguru P, Kurtz S and Rudolph J , reported the use of geopolymer composites to strengthened concrete structures as well as geopolymer coating to protect the transportation infrastructures. They reported that geopolymer composites have been successfully applied to strengthen reinforced concrete beams. The performance of geopolymers was better than the organic polymers in terms of fire resistance, durability under ultra-violet light, and did not involve any toxic substances.

Swamy R N and Sami A R Ali , carried out extensive investigations on the properties of fresh and hardened state of Fly ash concrete containing normal weight and light weight aggregate suitable for structural application. The mixes were proportioned to have one-day strength comparable with concrete without fly ash, possessing adequate cohesiveness and workability to enable them to be compacted into place easily in structural members. The authors have after conducting extensive tests on reinforced concrete structural members with fly ash and without fly ash concluded that reinforced fly ash concrete in beams and slabs exhibit structural performance similar to that of conventional concrete with adequate safety factor and predicted by existing codes. The authors have concluded on the basis of the data

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presented with Fly ash of controlled quality, structural concrete constructions can be designed to incorporate Fly ash up to 30 percent by weight of cement and that Fly ash concrete characteristic were in no way different from these of comparable normal concrete.

Priyanka , The beam undergoes different kinds of loading which causes cracks in the beam. These cracks and their location effect changes the natural frequency and mode shapes of the beam. In the current work the natural frequency of cracked and uncracked beam having one end fixed and other is simply supported is investigated numerically by using ANSYS software. The cracked beam having triangular crack of depth 2mm.Different crack locations are considered and results are compared with the beam having no crack. Structural steel and aluminium are considered as beam materials.

III. MIX DESIGN OF CONCRETE FOR TWO CASES

CASE 1

FINAL PROPORTION OF OPC CONCRETE & FINAL PROPORTIONS OF GPC CONCRETE

	Cement	F.A	C.A	Water	Super plasticizer
Ratio	1	1.16	2.45	0.3	0.03

	Silica Fume	F.A	C.A	Water	NaOH	Na_2Sio_3	Super plasticizer
Ratio	1	1.3	3.05	0.09	0.06	0.23	0.015

AMOUNT OF MATERIALS USED IN OPC & GPC COMPOSITION OF SILICA FUME

	OPC	GPC
	(Kg/m^3)	(Kg/m^3)
Cement	493	_
Silica fume	_	424.62
Fine Aggregate	575	555
Coarse aggregate	1210	1295
NaOH	_	28.31
Na_2SiO_3	_	99.08
Water	133	42.46
Super plasticizer	15	12.73

IV. METHODOLOGY

MATERIAL PROPERTIES OF CONCRETE:

	Density (Kg/m^3)	Young's modulus (N/mm^2)	Poission Ratio
OPC	2400	0.371×10^5	0.2
GPC	2420	0.386×10^5	0.24

MODELLING OF BEAM:

The analysis has been carried out for the comparison and the study of effect of OPC and GPC with experimental and ANSYS results. The beams modelled in ANSYS for the Loading.

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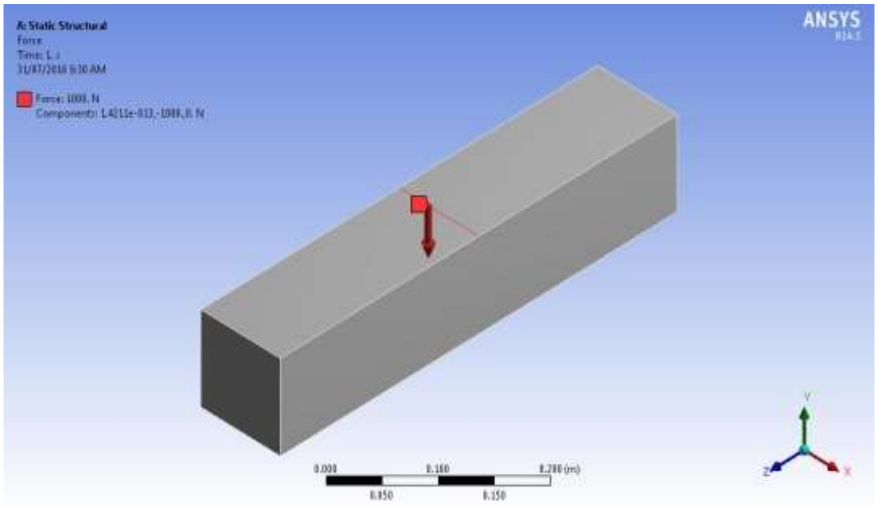


Figure 2: Modelling of plain beam

THE ANALYTICAL BEAM ANAYSIS:

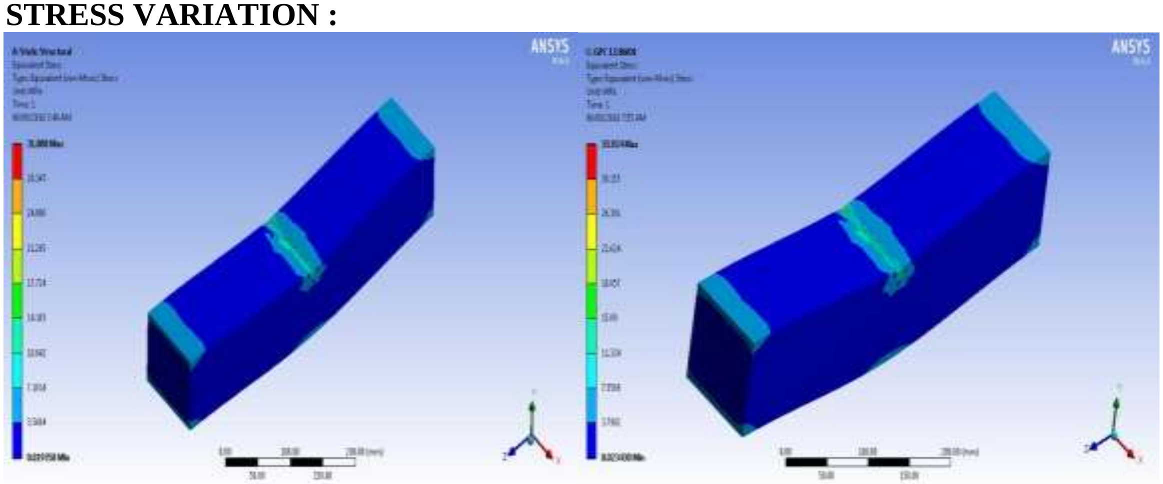
	Load (tonnes)	flexural Stress (N/mm^2)	Strain
OPC	13.1	31.8	0.0016
GPC	13.96	33.4	0.0015

EXPERIMENTAL RESULTS :

	Load (tonnes)	flexural Stress (N/mm^2)	Strain
OPC	13.1	6.54	0.00162
GPC	13.96	6.98	0.00163

THE STRESS –STRAIN VARIATION BETWEEN ANALYTICAL AND EXPERIMENTAL VALUES

- **STRESS VARIATION :**



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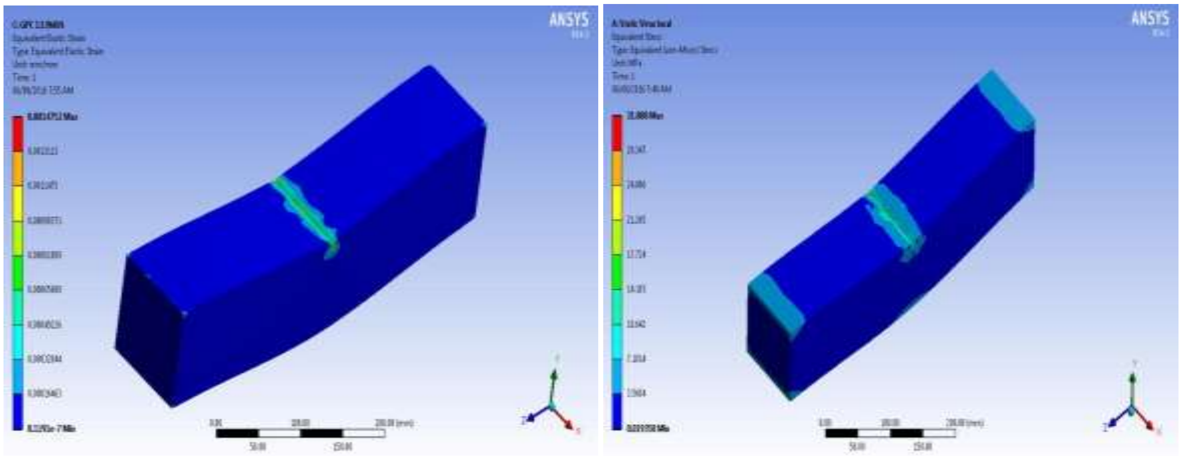
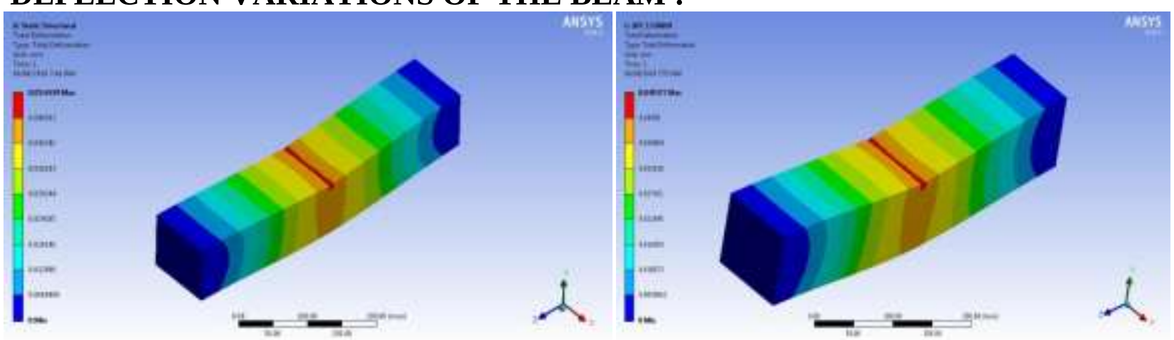
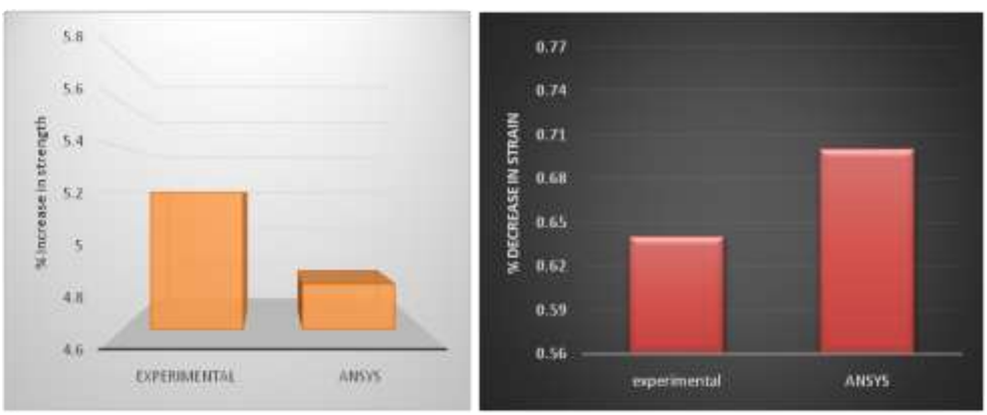
- **STRAIN VARIATION:**



- **DEFLECTION VARIATIONS OF THE BEAM :**



GRAPHS :



V. CONCLUSIONS

The project achievements are as follows:

1. GPC is having less deflection when compared to OPC.
2. The stress-strain parameters of GPC is less than OPC.
3. The amount of Failure cracks observed in both practical and software in the same zone.
4. The formation of cracks in concrete specimens both in GPC and OPC have occurred which were detailed and summarized in software
5. The mix of both the concrete are taken special attraction in this, where it is proven in practical

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test and also in software. Hence we can conclude the materials are conjoined in the specimens. From the cumulative results we can come to an conclusion than replacement of OPC with GPC can be done, which can bring the dual benefit such as preserving the natural resources and reduce the emission of green house gases into the atmosphere where it is proved in both theoretical and practical.

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