Hybrid Composite Beam

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Abstract— The use of "Hybrid-Composite Beam" or HCB, in the field of bridge engineering, gained a lot of attention. The HCB is made up of three main sub-components that are a composite shell, compression reinforcement, and tension reinforcement. only a limited number of researchers have studied in HCB. For its essential design methodologies and long-term performance. Here the power of finite element analysis is employed to derive a novel method from doing such analysis. ANSYS is used as the simulation tool for the analysis since it is one of the best proven FEA software in the world. It is decided to conduct a static structural analysis oh HCB and thereby obtaining HCB having better load carrying capacity. It is decided to conduct a parameter optimization for varying thickness of scc web and arch thickness. The expected results focused on the minimum equivalent stress and total deformation.

Key words: Hybrid Composite Beam, Compression Reinforcement, Tension Reinforcement

I. Introduction

The use of FRP composites as construction materials in structural engineering has gained a lot of attention recently. composites have many advantages over conventional construction materials (e.g., concrete and steel). Their high strength-to-weight ratio, corrosion resistance, dimensional stability, good durability, and high dielectric strength make them promising and valuable materials for use in both new construction and existing infrastructures. Although FRP composites can be used as an ideal solution for resolving a number of problems that face highway bridges (particularly corrosion and deterioration), their initial cost is relatively high when compared to more traditional materials used in civil engineering applications. But once its bulk manufacturing started, the problem of high can be solved. The use of FRP composites in the construction industry can be optimized by combining the composites with hybrid structural systems. These hybrid systems either combine GFRPs with CRFPs or integrate FRPs with conventional construction materials in structural members. The advantages of hybrid systems include their cost-effectiveness and the ability to optimize the structure based on constituent material properties. Several researchers have applied the hybrid FRP-concrete design concept to flexural members.

Hybrid composite beams (HCB)s consists of mainly three components which are a composite shell, compression reinforcement, and tension reinforcement. The shell is usually made up of a glass fiber reinforced polymer (FRP) box beam. Shell plays the role of protection of HCB elements from environmental effects and thereby increase the lifetime of HCB. The compression reinforcement consists of self-consolidating concrete (SCC) which is poured into a classical arch shape within the shell. The arch shape is provided for optimizing the use of concrete because we know that concrete strong in compression under service loads and thereby reducing the production of greenhouse gasses. Galvanized steel tendons or typical steel fibers are anchored at the compression reinforcement ends are used as tension reinforcement. The tension reinforcement used here should have a high modulus of elasticity and high tensile strength. So we are commonly using prestressing strands as tension reinforcement. Compression reinforcement and tension reinforcement are considered as the primary load carrying elements in HCB. The empty space within the shell is filled with polio foam due to its light weight, low cost. In this project am going to replace these traditional reinforcements by FRP composites usually of CFRP, GFRP, and AFRP and carrying out numerical modeling for ultimate load capacity. Finite element (FE) models of these structures are made by ANSYS software. In order to predict the deflections and the strains using the current design, mathematical calculations are available. This unique configuration of HCB that combines conventional materials into FRP or natural components creates a new structural element that utilizes the inherent advantage of each material in such a manner as to optimize the overall performance of the beam.

II. Static Structural Analysis

The static structural analysis is conducting on HCB(having unidirectional fibers as tension reinforcements) and determining the deformations, stresses, strains .it is conducted by using the best-proven software ANSYS.

A. *Description of materials & Properties:*

FRP Composites: The properties of FRP composites are shown in table 1

Elastic modulus (MPa)	Poissons ratio	Shear modulus (MPa)
Ex =27565	µxy = 0.26	Gxy=6336
Ey=15699	µxz =0 .26	Gxz=6336
Ez=15699	µyz= 0.3	Gyz =6038

Table 1: Properties of FRP Composites

Concrete: Self-consolidating concrete which is highly flowable is used for making compression reinforcement.

Elastic modulus and the maximum tensile strength are calculated by the following ACI 318-08

$$Ec = 57000\sqrt{fc}$$

fc=The compressive strength of concrete in Psi

Reinforcement: 3 types of reinforcement bars are used in HCB are unidirectional carbon, glass, aramid fibers. Properties of UD fibers are shown below

Properties	Epoxy Carbon UD (230 GPa) Prepreg	Epoxy E-Glass UD	Kevlar/ Epoxy

Ex (MPa)	1.21E+05	45000	91380
EY (MPa)	8600	10000	4000
Ez(MPa)	8600	10000	4000
µxy	0.27	0.3	0.35
µxz	0.27	0.3	0.35
µyz	0.4	0.4	0.484
Gxy (MPa)	4700	5000	2260
Gxz (MPa)	4700	5000	2260
Gyz (MPa)	3100	3846.2	1460
Density (Kg/m^3)	1490	2000	1400

Table 2: Properties of Ud Fibers

Wrapping sheets:3 types of FRP sheets are used in HCB.Usually, FRP sheets are used as wrapping sheets.Properties of wrapping sheets are shown in table 3.

Properties	AFRP	CFRP	GFRP
Ex (MPa)	13600	16500	21000
EY (MPa)	1482.1	9650	7000
Ez(MPa)	1482.1	9650	7000
µxy	0.32	0.3	0.26
µxz	0.32	0.3	0.26
µyz	0.35	0.45	0.3
Gxy (MPa)	549.13	5200	1520
Gxz (MPa)	549.13	5200	1520
Gyz (MPa)	547	3400	2650

Table 3: Properties of Wrapping Sheets

Polyisocyanurate Foam:polysio foam is used as the filler material in HCB.

Elastic modulus (Kpa)	Poissons ratio	Shear modulus (Kpa)
Ex =8440	µxy = 0.25	Gxy=1516
Ey=3190	µxz =0 .25	Gxz=1516
Ez = 463	µyz = 0.308	Gyz =1219

Table 4: Properties of Foam

III. Modeling of HCB in ANSYS

A. Member Specifications:

The properties assigned to the structural elements are as follows:

- HCB Of rectangular configuration Is Considered
- BEAM SHELL:730X730mm
  Span=10m
  11 Nos Of 12 Mm Dia Bars As Tension reinforcements
- Cover=40mm
- Gfrp box thickness=10mm
- Concrete shaft : 350x730mm
- Thickness Of Concrete Arch =100mm
- SCC arch width :650mm
- SCC arch span:4704 mm
- SCC web length:4650mm
- SCC web depth:623mm
- SCC web width :75mm

FE modeling of the structure is done using the ANSYS workbench, release 16.2, with the dimension of the structure from the reference journal.HCB is modeled as simply supported beams that have a pin support at one end and a roller support at the other end. The meshing of the structure is created using ANSYS Meshing, a general purpose meshing tool. The figures given below show the different views of the created model in ANSYS.

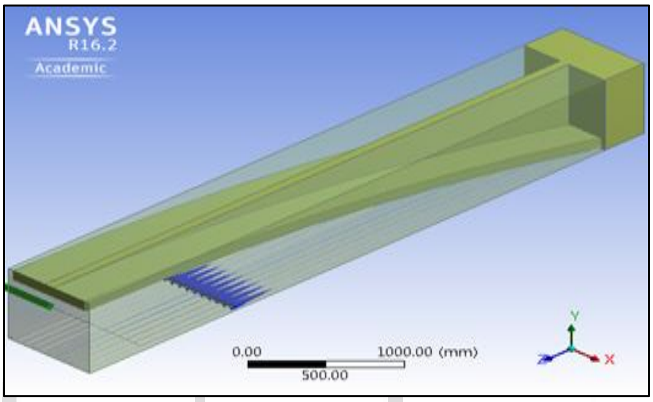

Fig. 1: Model of HCB

B. Meshing:

ANSYS Workbench 16.2 offers a wide selection of solvers. A final mesh of nodes 14479 and 8363elements was generated during the user controlled meshing process. Further fine meshing proved unnecessary since required convergence criteria were met after the initial trials.

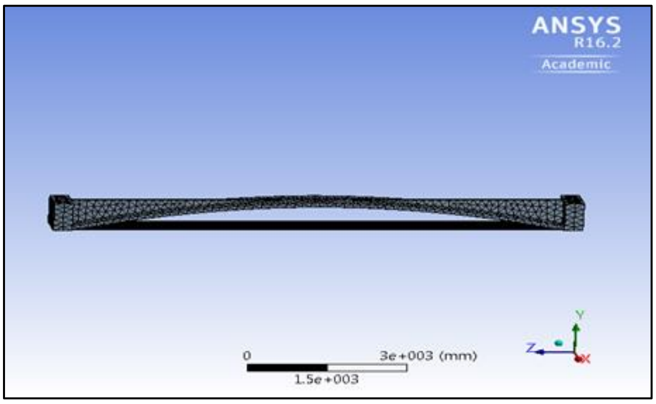

Fig. 2: Model after meshing

IV. Optimization

Based on the identified input and output parameters, parameter correlations can be determined which identifies strong and weak correlations between sets of input and output parameters. ANSYS design exploration also offers response surface generation and response surface optimization which is particularly suitable for cases with larger DoE sets. In this case, a direct optimization component (shown in project setup image above) is used for optimizing the thickness of scc web and arch.

- Input parameters: P1 &P2
  - P1: FRP web thickness
  - P2: Arch thickness
- Output parameters: P3&P4
  - allowable adjustment ranges
- P1 thickness
  - Lower bound:80mm
  - Upper bound:120mm
- P2 top thickness
  - Lower bound:60mm
  - Upper bound:85mm

Optimization method: The Screening optimization method uses a simple approach based on sampling and sorting. It supports multiple objectives and constraints as well as all types of input parameters. Usually, it is used for preliminary design, which may lead you to apply other methods for more refined optimization results.

Configuration: Generate 15 samples and find 3 candidates.

Status : Converged after 15 evaluations

TABLE .5

Name	P1	P2	P4	P3
Candidate Point 1	118.66 67	71.770 83	3.4542 69	7.2687 55
Candidate Point 2	116	78.020 83	3.5268 25	6.8831 51
Candidate Point 3	110.66 67	81.145 83	3.5344 5	7.2136 93

Table 5: Candidate Points

V. RESULTS AND DISCUSSIONS

In the static structural analysis, the multistep load is mainly used to study load case combination. It is not created by applying a time varying load. Even if you apply a time varying load, it will not have any effect on it because inertia is not considered.Here in the static structural analysis of HCB, we are concentrating on total deformation and von - mises stress generated in the specimen for the three different UD fibers as tension reinforcements and obtaining the HCB having high load carrying capacity.

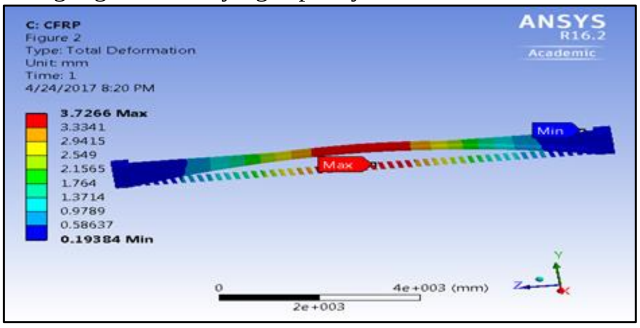

Fig. 3: Total Deformation Of HCB With CFRP

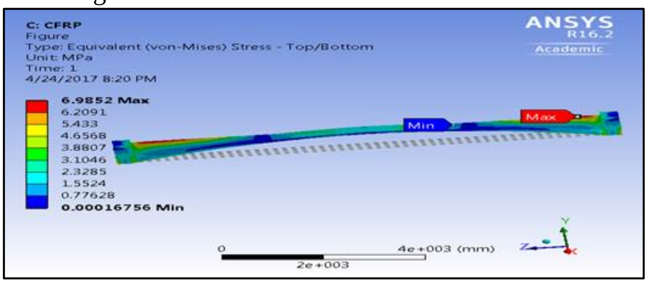

Fig. 4: Von-mises Stress of HCB With CFRP

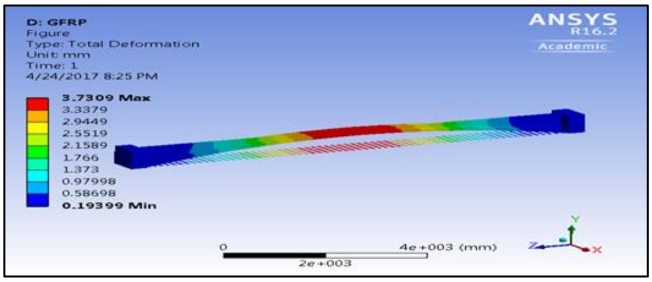

Fig. 5: Total Deformation of HCB with GFRP

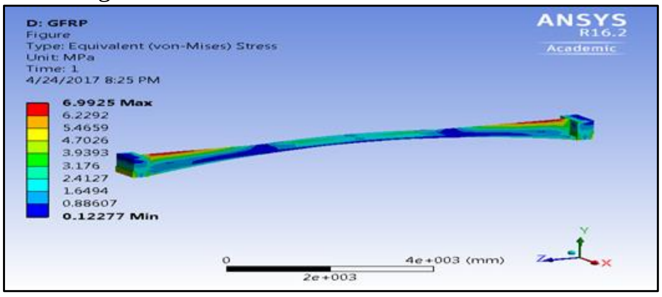

Fig. 6: von-mises stress of HCB with GFRP

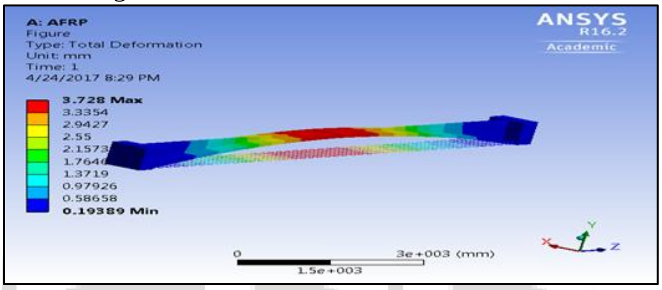

Fig. 7: Total deformation of HCB with AFRP

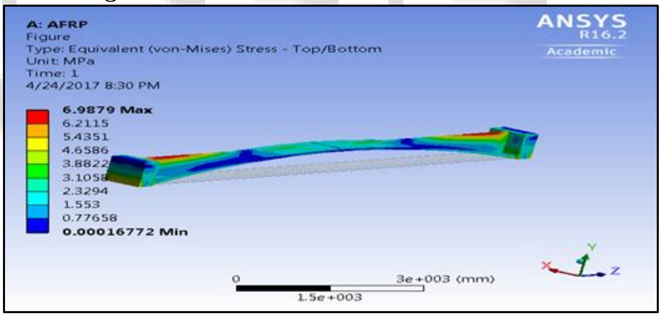

Fig. 8: Von-mises Stress Of HCB with AFRP

	CFRP	GFRP	AFRP
Total Deformation Of All Body(mm)	3.7266	3.7309	3.728
Equivalent Stress Of All Body(MPa)	6.9852	6.9925	6.9879
Normal Stress Of All Body(MPa)	6.0899	6.0867	6.0888

Table 6: Numerical Results Of Static Structural Analysis

From the static structural analysis of HCB with 3 different unidirectional fibers, it is observed that there are only slight variations in the deformation and stresses between these three.

However, carbon fiber shows better performance when compared to aramid and glass fiber.

In order to improve the load carrying capacity of HCB, we are going to provide wrapping sheet having 100mm thickness below the concrete arch with respective FRP sheets.After analyzing it, we obtained that while providing CFRP wrapping sheet HCB shows better performance when compared for HCB without wrapping.

	Without CFRP wrappi-ng	With CFRP wrapping	Without GFRP wrapping	With GFRP wrapping	Without AFRP wrapping	With AFRP wrapping
Equivalent stress (Mpa)	6.9852	5.97	6.882	6.792	6.987	6.894
Total deformation(mm)	3.726	0.98	3.730	1.070	3.728	1.103

Table 7: Results After Providing Wrapping Sheets

Load deflection graphical representation for HCB having unidirectional fibers are plotted and shown in below.

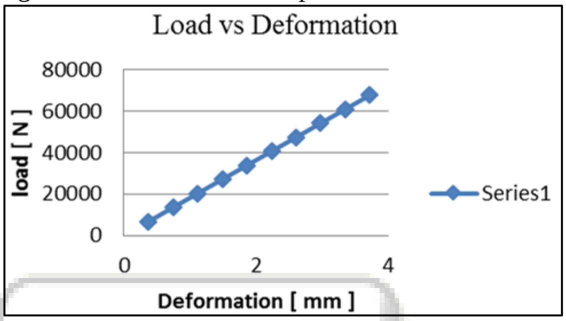

Fig. 10: Load- Deflection Graph Of HCB Having Carbon Fibers As Tension Reinforcement

From the load – deflection graph of HCB having carbon as tension reinforcement,it is inferred that maximum deformation corresponding to maximum load is 3.7266 mm.

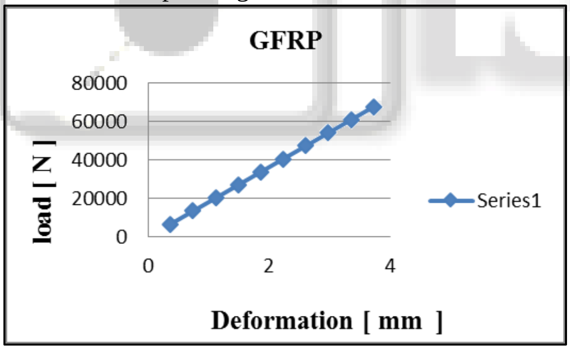

Fig.11: Load -Deflection Graph of HCB Having glassFibers As Tension Reinforcement

From the load – deflection graph of HCB having glass as tension reinforcement,it is inferred that maximum deformation corresponding to maximum load is 3.7309 mm

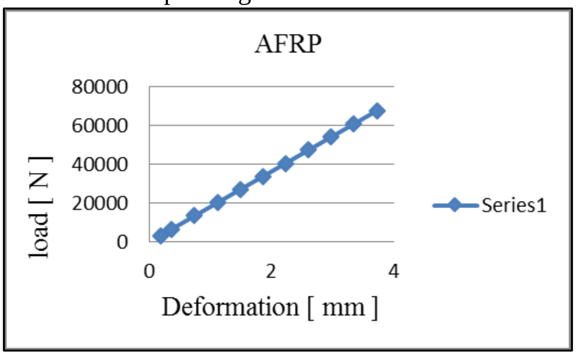

Fig. 12: Load -Deflection Graph Of HCB Having aramid Fibers As Tension Reinforcement

From the load – deflection graph of HCB having aramid fiber as tension reinforcement, it is inferred that maximum deformation corresponding to maximum load is 3.728 mm

VI. Conclusions

The following conclusions were drawn from numerical and mathematical analyses' results gathered during this research project:

– The expected results focused on the load bearing capacity of the hybrid beam and stresses generated in the specimen.
– It is proved that CFRP has the high load carrying capacity compared to glass and aramid fiber.
– The unique configuration of the HCB optimizes the load carrying behavior and maintains the gross section properties under the service loads.
– Deformation& stresses got reduced while providing wrapping.
– By varying the thickness of concrete web and scc arch .3 candidate points obtained which leads to less deformation and equivalent stresses from parameter optimization

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