REVIEW ON STRUCTURAL PERFORMANCE OF HONEYCOMB SANDWICH PANEL

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Abstract - Honeycomb cores are one of the most structurally efficient core constructions, especially in stiffness-critical applications. The basic idea of honeycomb panel was to use the honeycomb as a shear web between two skins. It provides minimal density and high out-of-plane compression and shear properties. It has high strength to weight ratio and good impact resistance. Structural properties of honeycomb structure depends it's lower and upper face sheet thickness, the core material thickness, cell diameter, cell angle and foil thickness. Debonding is one of the major failure modes of honeycomb sandwich panels. Material used for the honeycomb construction also has very important in its structural performance.

This study focused on the dynamic and static performance of honeycomb sandwich structures and their applicability in bridge deck constructions. This study investigates the effect of geometric parameters on the structural performance of the honeycomb structures such as lower and upper face sheet thickness, the core material thickness, cell diameter, and core configuration.

Key Words: Honeycomb sandwich structures, Glass Fibre reinforced polymer, sinusoidal core

1. INTRODUCTION

Reduction of mass has always presented a challenge to the Design Engineer. This led engineers to look to more efficient structures. In 1938, a patent application went through for honeycomb manufacture, by a company in the U.K called Aero Research Limited. The basic idea was to use the honeycomb as a shear web between two skins. At this stage the adhesive technology was not yet sufficiently developed to bond skins directly on to Honeycomb. The engineers, seeing the benefits of a lightweight expanded core with integral skins, carried on with the development of using end grain balsa as a core, bonded to plywood skins. This particular sandwich or bonded structure was used extensively on the Mosquito and Vampire Aircraft. The development of Epoxy Resin made possible the bonding of aluminum skins to aluminum Honeycomb. This occurred in 1954. Since then many developments in the honeycomb field have taken place. Honeycomb sandwich panels are now used in various applications of civil, aerospace, and mechanical structures because of their high strength-to-weight ratios, desirable acoustic properties. Standard aluminum skinned panels can be used for Brattice walls and they can used to replace I.B.R sheeting, thus keeping labour costs down. Mild or galvanized steel panels with aluminum cores can be used for skips or cages. Glass Phenolic skinned, aluminum cored can used for light weight partitioning and light weight platforms. Pure aluminum Honeycomb used as an absorber of energy. FRP and steel honeycomb panels can use for lightweight bridge deck. The material is also used for partitions, Aircraft galleys, and overhead bins. The use of Honeycomb makes it possible to eliminate buckling of the thin skins and provide the exact amount of shear strength required to do the job. They are stronger, stiffer, lighter fire retardant, good impact resistant and give a much better surface finish.

Hence, this study focuses on the structural behavior of honeycomb sandwich composites panel used as bridge deck. Study looked for a suitable honeycomb core configuration and material combinations for honeycomb deck panel through numerical analysis. The study also go through the parametric study of panel such as the effect of lower and upper face sheet thickness, core material thickness, cell diameter, cell wall thickness, and core geometry.

Traditionally, most highway bridge decks were constructed with steel-reinforced concrete. The life-span of such materials can be greatly reduced by weathering. It is also affected by traffic, chemicals, and reduced maintenance. Transportation agencies have been trying to identify new, cost-effective, reliable construction materials. Fiber reinforced polymers (FRPs) have exhibited in eliminating corrosion concerns while also achieving a longer lifespan without requiring frequent maintenance. An FRP bridge deck weighs approximately one-fifth that of a reinforced concrete bridge deck. The FRP sandwich panel is composed of two thin facings that are bonded to a thick core. These facings are typically comprised of materials that have a high strength and high Young's modulus. To improve the structural performance of FRP decks, honeycomb core sandwich panels have been used. Different configurations of core such as sinusoidal core, hexagonal core, rhombus core etc are performing differently. Figure 1.1 show a honeycomb sandwich panel. The geometry of this sandwich structures are designed to improve the stiffness and buckling responses by the continuous support of core elements with the face laminates.

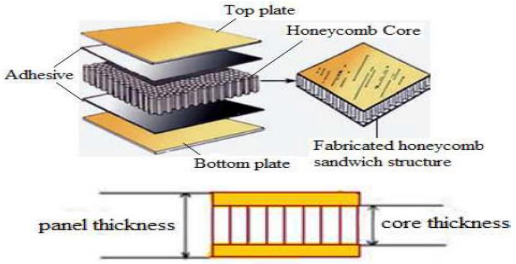


Fig.1.1: Honeycomb sandwich panel

Sandwich structures usually consist of a pair of thin stiff, strong face sheet (faces facings or covers), a thick, lightweight core to separate the skins and carry loads from one skin to the other, and 3) an adhesive attachment it is capable of transmitting shear and axial loads to and from the core. The separation of the face sheet by the core increases the moment of inertia of the panel with little increase in weight, producing an efficient structure for resisting bending and buckling loads. Study of behavior of different structural responses generated from inherent statistical variations of stochastic material and geometric parameters of honeycomb structure is very important.

2. LITERATURE REVIEW

Arunkumar M.P. et.al, [2016] presents the study of influence of core geometry on vibration and acoustic response characteristics of sandwich panels which are used as aerospace structures. Commercial finite element software ANSYS has been used to carry out the vibration response analyses while code built-in-house using MATLAB for the Rayleigh integral has been used to obtain the sound radiation characteristics. In honeycomb core sandwich panel the effect of face sheet thickness on vibration and sound radiation characteristics are significant. One can select cell size as the parameter to reduce the weight without affecting the sound and vibration characteristics.

Mehdi Tehrani1 et al [2016] investigate the effect of geometric parameters including thickness of core and face sheets, panel height, spot weld distance, and spot weld radius on the mechanical behavior (deflection and shear force) of a corrugated-core steel sandwich panel. To reduce the complexity of geometry in the finite-element modeling simulation, the size of the model is reduced to a quarter model by applying symmetry planes. Based on the application of the sandwich panels, core geometries for the panels can be designed in different forms and shapes. The obtained results from full factorial analysis with five geometric parameters revealed that core and face sheet thicknesses are the most important factors because they have significant contributions (41% for each) to the panel maximum deflection response.

Sakar G. and Bolat F.C. [2015] carried out free vibration analysis of aluminum honeycomb sandwich structures, experimentally and numerically. The natural frequencies and mode shapes of sandwich structures fabricated with different configurations for clamped-free boundary condition were determined. The effects of lower and upper face sheet thickness, the core material thickness, cell diameter, cell angle and foil thickness on the vibration characteristics were examined. The numerical studies were performed with ANSYS package. In the analyses it was observed that when the cell diameter was increased the first natural frequency decreased. The cell angle (θ) has little effect on the first natural frequency. When the foil thickness and core height were increased the first natural frequency was increased. It was determined that the most effective parameter on the natural frequency on the sandwich beam was core height.

Nagasankar P. et.al. [2015] investigates the effect of different orientations of fiber in the skins and different thicknesses of the skins and polypropylene honeycomb core (PPHC) on the transverse shear damping of the sandwich using experimental and theoretical studies. In order to study the effect of fiber orientation of the skin on the natural frequency and loss factors, five different orientations (all 0^o, $\pm30^o$, $\pm45^o$, $\pm60^o$ and all 90^o) were considered. An impulse technique was used to calculate the natural frequency and loss factor of the composites. The natural frequency and loss factor were also computed theoretically and compared. The transverse shear effect and damping loss factor increases with the increase in the thicknesses of the skins and core of the sandwich.

Salini Theres N. Kurian et.al, [2013] conducted an analytical study on the fatigue behavior of GFRP bridge deck panels. Finite element software ANSYS is used for modeling and analyzing multi-cellular GFRP bridge deck panels. Result show that GFRP deck panel is a suitable alternative for RC panels.

Nicolas J. Lombardi et.al, [2011] conducted GFRP-steel hybrid parametric studies to evaluate improvements on the GFRP honeycomb deck panel stiffness. Possible configurations included the embedment of steel plates within the face sheets and the placement of steel tubes within the core. Core stiffness analyses were also performed. An experimental study, including large-scale beam tests, was conducted. The large-scale tests were performed to assess the equivalent flexural and shear stiffness, comparing the hybrid steel core concept and the current GFRP core design. From the large-scale beam test results, an overall stiffness increase was observed.

Wenchao Song et.al, [2011] conducted experimental study about the behavior of honeycomb fiber-reinforced polymer (HFRP) sandwich structure with corrugated cores under the combined effects of service load and low-temperature cycling (ranging from 24°C to 35°C). The debonding at the interfaces between the corrugated cores and face sheets because of the service-load condition specific to bridge engineering at low temperatures and its impact on stiffness are studied. ABAQUS software used for the finite-element analysis (FEA) .The resin matrix and glass fiber used in the specimens are polyester and E-glass. The experiment consisted of tests conducted at four different temperatures. The load-strain responses were monitored to study the behaviors of HFRP sandwich panels. This study concludes that the deflection limit span over 400 can potentially be adopted in practice without incurring stiffness degradation because of interface debonding. The stiffness of the HFRP sandwich panels at the service-load level will increase when the temperatures are decreased.

Benson Shing P. et.al, [2010] investigates the performance of a glass fiber-reinforced polymer (GFRP) bridge deck under static and fatigue load cycles. The bridge deck has a sandwich panel configuration, consisting of two stiff face shells separated by a light-weight honeycomb core. In this study, a full-size panel that had the same design as an actual bridge deck was tested. The experimental data are analyzed and compared to the results of finite element analysis. The data obtained have indicated that the failure of the system is governed by the delamination of the face shells from the honeycomb core.

George Morcous et.al, [2009] presents the analytical and experimental investigations performed to evaluate the structural behavior of Fiber-Reinforced Polymer Honeycomb Sandwich Panels (HCSPs) used for bridge decks. The analytical investigation includes modeling FRP HCSPs using three Finite Element Models (FEM) and a simplified I-beam model. Finite Element Analysis includes one-layer modeling, three-layer modeling, and actual configuration modeling. The fourth method, designated as simplified I-beam modeling, is based on the analysis of an equivalent I-beam using transformed area method. Based on the analytical investigation simplified I-beam was found to be the most efficient and reliable method to study the overall performance of the FRP HCSP. Two failure modes in static testing were observed: delamination and compressive failure. Delamination between the core and face layers was the major mode of failure in FRP HCSP.

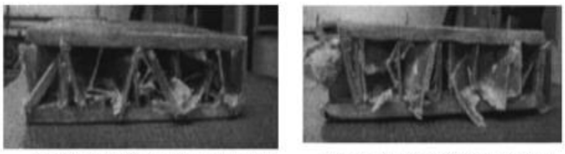
Ke-peng Qiu, et.al [2009] study the bending and dynamic responses of sandwich panels with the size variation of different sandwich cores and the homogenized cores are analyzed numerically, including the hexagonal and rectangular cores, the square and rhombic cores and the circle and X-shape corrugated cores. In dependence on the ratio of the span dimensions to thickness, the laminate plate theory is also adopted for the static and dynamic analysis of sandwich panels with the homogenized cores. Study shows that the size effect of cores is very obvious and important for the structural response of sandwich panels.

Gaetano G. Galletti et.al, [2007] discusses the theoretical and quantitative design and analysis of a honeycomb panel sandwich structure. The initial design is based on specific requirements that the panel must achieve prior to failure under load. Materials to be used for the facing and core are selected based on the given requirements. With the materials chosen, the facing sheets and core are analyzed for failure. Failure occurs when the stresses in the panel exceed the properties of the materials by any mode.

Wahyu Lestari et.al, [2006] conducted a combined analytical and experimental study of dynamic characteristics of honeycomb composite sandwich structures in bridge systems. The composite sandwich beams are made of E-glass fiber and polyester resins, and the core consists of the corrugated cells in a sinusoidal configuration. Based on the modeling of equivalent properties for the face laminates and core elements, analytical predictions of effective flexural and transverse shear stiffness properties of sandwich beams along the longitudinal and transverse to the sinusoidal core wave directions are first obtained. This study can be used as an effective tool to assess the bending and transverse shear stiffness properties of composite honeycomb sandwich structures with relatively thick face sheets, and the evaluated mechanical properties can be adopted in highway design and structural health assessment.

Guido Camata et.al, [2005] presented a study on the evaluation of the static performance of a glass fiber-reinforced polymer (GFRP) honeycomb bridge deck that was installed in O'Fallon Park over Bear Creek west of the City of Denver. The configuration of core and face sheet of panel is shown in fig. 2.1. The crushing capacity of the panel was also examined by subjecting four 330×305×190 mm (13×12×7.5 in.) specimens to compression tests. The experimental data were analyzed and compared to results obtained from analytical and finite element models, which have been used to enhance the understanding of the experimental observations. The failure of all four beams was caused by the delamination of the top faces. Failure of panel is shown in fig. 2.1. Results indicated that increasing the face thickness increases the flexural stiffness of a beam.

Test 1- 9.525 mm face thickness Test 2- 9.525 mm face thickness



Test 3- 12.70 mm face thickness Test 4- 12.70 mm face thickness

Fig.2.1: Crushing failure of honeycomb panel

Prakash Kumar et.al, [2004] conduct Fatigue and failure tests on a 9.144 m long by 609.6 mm wide prototype deck sample, equivalent to a quarter portion of the bridge deck. The loads for these tests were computed so as to meet American Association of State Highway and Transportation Officials (AASHTO) H-20 truckload requirements based on strength and maximum deflection. Stiffness changes were monitored by periodically interrupting the run to perform a quasi-static test to service load. Results from these tests indicated no loss in stiffness up to 2 million cycles. Following the fatigue testing, the test sample was tested to failure and no loss in strength was observed. The study also discussed the design of the bridge deck in detail.

By X. Frank Xu et.al, [2001] done an analytical approach with a two-scale asymptotic homogenization technique is developed for evaluation of effective transverse shear stiffness of thin-walled honeycomb core structures with general configurations, and the governing 3D partial differential equations are solved with the assumptions of free warping constraints and constant variables through the core wall thickness. A detailed study is given for three typical honeycomb cores consisting of sinusoidal, tubular, and hexagonal configurations, and their solutions are validated with existing equations and numerical analyses. The developed approach with certain modifications can be extended to other sandwich structures, and a summary of explicit solutions for the transverse shear stiffness of common honeycomb core configurations is provided.

3. CONCLUSIONS

From the above literatures it is find out that, honeycomb sandwich panel are used in many civil structures such as bridge and pedestrian decks, roof panels, railway sleepers, bridge beam etc. Their properties like high stiffness to weight ratio, high thermal insulation property, and high impact and vibration absorption rates are very useful for civil structures. The structural behaviour of honeycomb sandwich panel depend upon the parameters such as core height, face sheet thickness, cell size, cell thickness, cell geometry etc. The structural behaviour of honeycomb panel can change by making changes in the parameters accordingly. In different studies, a concrete deck is suggested to be replaced with honeycomb sandwich panels for bridge deck applications because of its high strength to weight ratio and easy installation possibilities. GFRP honeycomb panels are best for the bridge deck. They are light weight and corrosion resistant compare to concrete and steel.

REFERENCES

[1] Allan Manalo, Thiru Aravinthan, Amir Fam And Brahim Benmokrane (2016), State of-the-art review on FRP sandwich systems for lightweight civil infrastructure, Journal Of Composites For Construction, ASCE, 1090-0268.

[2] By X. Frank Xu, Pizhong Qiao and Julio F. Davalos (2011), Transverse shear stiffness of composite honeycomb core with general configuration, Journal of Engineering Mechanics, ASCE, Vol. 127(11), 1144-1151

[3] C.C. Foo, L.K. Seah and G.B. Chai (2007), Low-velocity impact failure of aluminium honeycomb sandwich panels, Composite Structures 85, ELSEVIER, 20–28

[4] G. Sakar and F. C. Bolat (2015), The free vibration analysis of honeycomb sandwich beam using 3D and continuum model, International Journal of Mechanical, Aerospace, Volume 9(6), 1061-1065.

[5] George Morcous, Yong Cho, Adel El-Safty, and Genmiao Chen (2010), Structural behavior of frp sandwich panels for bridge decks", ksce journal of civil engineering, ELSEVIER, Volume14(6),879-888

[6] Guido Camata and Benson Shing (2005), Evaluation of GFRP honeycomb beams for the o'fallon park bridge, Journal Of Composites For Construction, ASCE, Vol. 9(6), 545-555

[7] Guido Camata and P. Benson Shing (2010) ,static and fatigue load performance of a gfrp honeycomb bridge deck, Composites: Part B 41, ScienceDirect, 299–307

[8] Ke-peng Qiu, Wei-hong Zhanga, Ji-hong Zhu (2009), Bending and dynamic analyses of sandwich panels considering the size effect of sandwich core, International Journal for Simulation and Multidisciplinary Design Optimization, Optim. 3, 370-383

[9] Mehdi Tehrani, Farshad Hedayati Dezfuli, and M. Shahria Alam (2016), Parametric study on mechanical responses of corrugated-core sandwich panels for bridge decks, Journal of Bridge Engineering, ASCE, 1084-0702

[10] M.P. Arunkumara, K.V. Gangadharana and M.C. Lenin Babu (2016), Influence of nature of core on vibro acoustic behaviour of sandwich aerospace structures, Aerospace Science and Technology 56, ELSEVIER, 155–167.

[11] Nicolas J. Lombardi and Judy Liu (2011), Glass fiber-reinforced polymer/steel hybrid honeycomb sandwich concept for bridge deck applications, Composite Structures 93, ScienceDirect, 1275–1283

[12] Pizhong Qiao and Mijia Yang (2007), Impact analysis of fiber reinforced polymer honeycomb composite sandwich beams, Composites, ELSEVIER, Part B 38, 739–750.

[13] P. Nagasankar, S. Balasivanandha Prabu A and R. Velmurugan C (2015) ,Role of different fiber orientations and thicknesses of the skins and the core on the transverse shear damping of polypropylene honeycomb sandwich structures, Mechanics Of Materials 91, ELSEVIER, 252–261

[14] Salini Theres N. Kurian, Jiji Anna Varughese and Divya K.K (2013), Fatigue analysis of glass fiber reinforced polymer(gfrp) bridge deck panels,

International Journal of Innovative Research in Science, Engineering and Technology, Volume 2, Special Issue 1

[15] Wahyu Lestari and Pizhong Qiao and M.ASCE (2006), Dynamic characteristics and effective stiffness properties of honeycomb composite sandwich structures for highway bridge applications, Journal of Composites for Construction, ASCE, Vol. 10(2), 1090-0268

[16] Wenchao Song and Zhongguo John Ma and F. Asce (2011), Behavior of honeycomb FRP sandwich structure under combined effects of service load and low temperatures, Journal Of Composites For Construction, ASCE, Vol. 15(6), 985-991.