Finite Element Analysis of Fiber Cement Corrugated Roofing Sheet under Bending

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Abstract—The study presents a numerical model for evaluation of the stresses in corrugated sheets under bending. The numerical analysis was performed from a three dimensional finite element model. From the analysis, the most intense tensional stress occurs in the trough and bottom surface of the corrugated sheet. While the most intense value of compressive stress occurs in the crest and top surface of the sheet. Based on the principal stress contour diagram, the researcher also observed that the maximum uniformly distributed load carrying capacity of the fiber-cement corrugated sheet under bending, considering the linear material properties is 710N.

Index Terms—Fiber Cements, Corrugated Sheet, FEA Analysis, Longitudinal Stress, Principal Stress.

I. INTRODUCTION

Fiber cement products have been widely produced and sold all around the world for about a century. Examples of those products are corrugated sheets for roofing, flat panels for sliding, façades and partitions [1]. Corrugated roofing system is most preferred and widely used in rural and industrial areas of Nigeria because it allows mechanical and dry consumption methods to cover large areas without the need for ceiling compounds to prevent leakage [2].

In general, the test load of corrugated sheets is of large interest to fiber-cement industries which serves as a parameter for rejecting or acceptance of the lots of sheets produced. Asbestos cement is known to be a very durable material yet little has been published on this topic relating to its flexural responses. Instead, most of the published literatures about fiber-cement sheets discuss asbestos-free composition with significant interest given to the durability of the organic fiber. However, according to [3], the technology of producing this fiber cement without asbestos has presented unsatisfactory results due to the high production cost and low mechanical performance of the component. Alternatively, engineers have solved this problem by reinforcing these cement composites with functionally graded fibers by varying its properties in a local way [4].

Although there have been social motivations within the Nigerian society to ban asbestos fibers having been linked to the sources of many diseases, it is important to analyze the responses of this product to bending.

This study presents a numerical analysis of the stresses on corrugated roofing sheets to determine the maximum uniformly distributed load carrying capacity of the fiber cement corrugated roofing sheet under bending. Numerical methods provide a general tool to analyze arbitrary geometries and loading conditions [5]. Among these numerical methods, Finite Element has been extensively used with success [2]. However different approaches for the numerical simulations can be considered: a linear elastic analysis with geometrical non-linearity or a physical nonlinear analysis [3]. The linear elastic analysis is easier to perform and can be used in determining the response of any structural element in their global three dimensions. For this analysis, the 3D model was created considering the physical linearity of the material (stress is proportional to strain) and geometrical non-linearity of the sheet (deformation configuration) [6].

Fig. 1. Fibre cement corrugated sheet

Fig. 2. Finite element model of the fibre cement corrugated roofing sheet showing element surface
II. METHODOLOGY

The analysis of the fiber cement roofing sheet was carried out using Lisa finite element analysis software. Lisa requires input data for material properties as follows:

| Material                  | Properties       |
|---------------------------|------------------|
| Fiber cement              |                  |
| Young modulus             | 9mpa             |
| Poisson ratio             | 0.2              |
| Ultimate tensile strength | 13.2mpa          |

The discretization of the 3D model was performed in LISA by using quadratic shell elements supplied by nine nodes, six degrees of freedom per nodes and quadratic interpolation function with reduced integration. The element has three types of shape function which are associated with corner nodes, middle nodes and centre nodes respectively.

III. BOUNDARY CONDITION

The main objective in this paper is to understand the mechanical behavior of corrugated sheets under bending. The specimen was modeled with linear finite element models. To simulate the bending test of the corrugated sheets considering the dimensions indicated above with an applied load of 2500N at distance of 0.2m each, a fixed support condition was given at the ends of the sheet. The linear solution was carried out and the model solution was obtained both for the nodes and elements.

IV. RESULT AND DISCUSSION

The numerical result showed good agreement with the results obtained from other authors [4].

The result of the simulation showed that the maximum tensile stress acted on the trough area, the bottom surface and the central cross section of the corrugated sheet with a maximum tensile stress value of 0.1577MPa, 0.1112MPa and 0.06479MPa respectively. While the maximum compressive stress occurs in the crest and the flat area between the crest and the troughs with maximum compressive stress value of -0.2139MPa and -0.2604MPa respectively.

More so, according to the principal stress theory, failure will occur when the maximum principal stress in a system reaches the value of the maximum strength at elastic limit in simple tension test. From the contour diagram below, the maximum normal stresses that occurred at the principal plane 1 for a maximum applied load of 710N was located at the flanks in wave 1 & 2 with a value of 13.03MPa. While
the maximum normal stress occurring at the principal plane 2 was located at the bottom surface of wave 3-4 and at upper surface of wave 1&6 respectively with a maximum value of 2.398MPa. Although these values were lower than the ultimate tensile strength of the fiber-cement corrugated roofing sheet, addition of further load will induce the roofing sheet to tend to plastic deformation. Therefore, the stress intensity shows that 710N is the ultimate load carrying capacity of the roofing sheet.

V. CONCLUSION

A corrugated fiber-cement roofing sheet was modeled and analyzed under static flexure. From the result of the finite element analysis, the following conclusion was drawn: The maximum uniformly distributed load carrying capacity of the corrugated fiber cement roofing sheet with linear material properties is 710N.

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