Experimental Investigation And Static Analysis of Bridge Deck Panel By Using Aluminium Metal Matrix Composite

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Abstract - *Aluminium metal matrix composite(AMMC) are known for their excellent mechanical properties compared to aluminium base alloy. Aluminium alloy in structural application such as bridge deck, roofing frame and domes etc. By choosing appropriate ceramic reinforcements and combining them with aluminium alloy can yield AMMC of superior quality. The present work focused on develop of AMMC, consisting of aluminium base alloy 6061 as base alloy and Silicon carbide(SiC) and Alumina (Al_2O_3) as ceramic reinforcements, by stir casting method. This paper also aims to study and compare the properties such as rockwell hardness, tensile strength, impact strength of Al alloy 6061 and AMMC. mechanical properties was found to be superior than Al alloy 6061. Extruded deck panels were modeled in ANSYS. AMMC and Al alloy 6061 were assigned to the same model and total deformation under IRC class a loading was obtained. On comparison of result, AMMC deck panel was found to have minimum total deformation than aluminium alloy 6061 deck panel.*

Key Words: AMMC, Al alloy, SiC, Alumina, Stir casting, Total deformation, IRC loading

1.INTRODUCTION

Deck is a super structural element of a bridge and is considered as the most susceptible element of a bridge. the main problem in the highway system is its Bridge deck deterioration .The Use of advanced material for bridge deck system is a long-term solution for the deterioration problem for decks made up of concrete[8]. The recently developed redecking systems are grouped according to the material used and these includes the conventional materials such as concrete, steel, timber and modern advanced materials like engineered cement composite, aluminium alloys and FRP composites. The recent progress of engineering which lead to the development of a new generation aluminium alloys with excellent strength and durability did lead to a wider utilization of this material in structural and transportation engineering[5]. Aluminium is most commonly used for relatively small bridges. Specially developed extruded deck profiles are used in aluminium bridges. By welding the deck profiles together at the top and bottom flanges, almost an ideal isotropic bridge deck structure are obtained[9]. In this research, a new type of material such as aluminium metal matrix composite (AMMC) is used in bridge deck panel instead of aluminium alloy. The aim involved in designing metal matrix composite materials was to combine the desirable attributes of metals and ceramics[4]. For the study and conducting experiment, first we should know about the Metal Matrix composites. Aluminium alloys usually embedded with various particulates is universally known as the aluminium matrix composites (AMCs), and have been the subject of many researches in the past two decades owing to their superior properties[2]. Conventional monolithic aluminium alloy fails to meet the rising demand for high performance. Metal matrix composites (MMC) are metals reinforced with metal, ceramic or organic compounds, made by dispersing the reinforcements in the metal matrix. The addition of high strength, high modulus refractory particles to a ductile metal matrix produces a material whose mechanical properties are intermediate between the matrix alloy and the ceramic reinforcement[6].

The study focused on evaluating the static response of a 2.1 m x 3.2 m deck panel. The evaluation of the deck panel for service loads and ultimate load response information from finite element models are presented in this report. The analysis of bridge deck has been carried out under IRC Class A vehicle load as specified by IRC6, 2001.

2. EXPERIMENTAL WORK

In this work aluminium alloy 6061 is selected as matrix while Silicon carbide(SiC) and alumina (Al_2O_3) in powder form are reinforced. Alloy 6061 is the most popular of all aluminium alloys and has an yield strength comparable to mild carbon steel. Test specimen is prepared with the reinforcements of 8 weight % of SiC and 3 weight % of Al_2O_3 on Al 6061 aluminium alloy. Stir casting technique is used to prepare the AMMC test specimen . Al 6061 aluminium alloy is charged in the electric furnace and superheated to a temperature of 850^{0}C. SiC/Al_2O_3 particulates are preheated to a temperature of 400^{0}C for 1 hour in an oven to remove moisture and absorbed gases and also to refrain the huge drop in liquid metal temperature after the addition of the particles. The molten metal is then stirred at a speed of 450 rpm for 2 min with the help of impeller to create the sufficient vortex. The stir speed chosen is high enough to get a sufficient vortex for proper mixing of the ceramic particles with the liquid metal and at the same time it is low enough to avoid the gas and air entrapment in the liquid metal. The mechanical properties of reinforcements are shown in table 1 and stir casting equipment shown in fig.1.

Table -1: Mechanical properties of Al_2O_3, SiC [7]

Properties	Aluminium Oxide	Silicon Carbide
Density (g/cm³)	3.98	3.30
Tensile Strength (MPa)	416.0	588.0
Coefficient of Thermal Expansion (10-6/°C)	7.4	4.6
Modulus of Elasticity(GPa)	380	345

Figure-1: Stir Casting Equipment

2.1 Mechanical Testing

After completing the casting process the final product of aluminium metal matrix specimen is tested. The testing is conducted to calculate the properties of developed specimen. In this research we are calculating the hardness number, impact strength, tensile strength, and density. Specimen for tensile and impact test are shown in fig.2.

Fig.ure -2: (a)Tensile specimen(b)impact specimen

Table -2: Comparison of mechanical property of Alloy 6061 and AMMC

Material property	Alloy 6061 [7]	AMMC
Hardness(RHN)	59	63
Ultimate tensile strength(Mpa)	180	278
Impact(Nm)	4	10
Density(g/cm^3)	2.7	2.6

This present study reveals that the impact strength and hardness of particle reinforced metal matrix composites is more than the base Al 6061 alloy. This is due to proper dispersion of SiC& Al_2O_3 in to the matrix or strong interfacial bonding in between the Al alloy 6061 and SiC& alumina interface . Tensile test results shows that the AMMC material has the ultimate tensile strength property when compared to alloy 6061. Increase in strength due to the thermal mismatch between the metallic matrix and the reinforcement, which is a major mechanism for increasing the dislocation density of the matrix. From table 2 it is clear that the Aluminium metal matrix composite is far better in all perspectives when compared to the Aluminium alloy 6061.

3. FINITE ELEMENT ANALYSIS

The finite element software ANSYS is used for the modeling and analysis of multivoid AMMC and Al alloy deck panels by static analysis. Analysis is carried out on models created using ANSYS by taking IRC class A loading. The aluminum bridge deck has a multi-voided structure. These voids arise from the hollow extrusions are used to construct the deck. These extrusions are welded together at the top and bottom flanges to form a deck section 2.1 m wide and 3.2 m long. The cross sections considered for analysis are shown in Figure 3. Meshing is basically the division of the entire model into small cells, so that at each and every cell the equations are solved. It gives an accurate solution and also improves the quality of solution . Here the element size of 40 mm with medium smoothing is considered for mesh generation. Meshing and model of bridge deck are shown in fig.4.

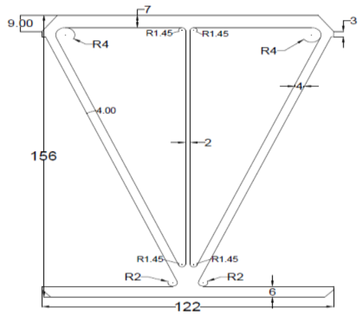


Figure - 3: Geometry of deck panel(All dimension in mm)

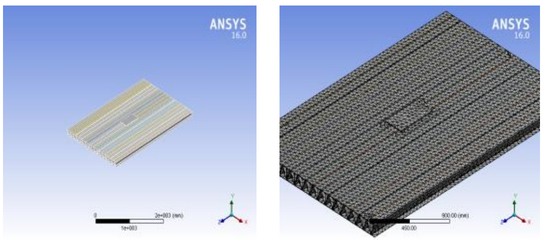


Figure - 4: Modeling and meshed model of bridge deck panel

3.1 Material Property

The material properties needed for the 3-D bridge deck models are Aluminium metal matrix composite and Aluminium alloy 6061. Table 3 lists the values used in this study.

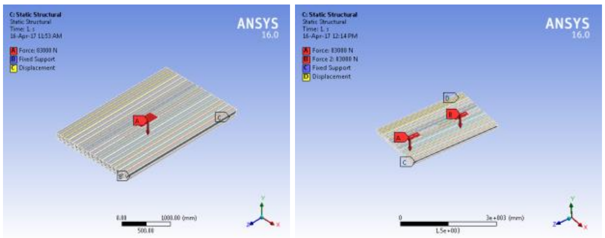
Table -3: Material properties of the aluminium metal matrix composite and al alloy 6061 without heat treatment

Material property	AMMC	Al Alloy 6061[7, 10]
Ultimate tensile strength f_u(MPa)	278	180
Modulus of elasticity (GPa)*	75	75
Poisson's ratio υ*	0.3	0.33
Density (g/cm³)	2.6	2.7

*Assumed values Modulus of elasticity, Poisson's ratio [10]

3.2 Loading And Boundary Condition

The deflection produced by the factored load must be less than the limiting value of the deflection. Class A wheel load of 57 kN is considered as the live load. The deck panel are gradually loaded from zero to a factored load of 83 kN (wheel load of 57kN+30% of impact factor +DL of future wearing surface). The bridge deck panel is simply supported over shorter spans and a rectangular patch load that represents the IRC Class A wheeled vehicle is applied over a patch area of 500 mm x 250 mm. The analysis has been carried out by considering two load case . Case (1) load placed at the centre of deck and Case(2) load is placed symmetrically at the centre of deck panel are shown in fig.

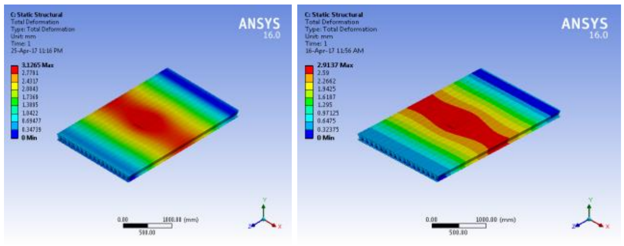


(a) (b)

Figure - 5: Load applied (a) case 1 (b) case 2

3.3 ANSYS Simulation

The static analysis is used to find out the total deformation of deck panel under IRC class A. The static analysis of the deck panel is done by ANSYS software. Static Analysis of Aluminium alloy deck panel and Aluminium metal matrix composite deck panel are shown in figure .



(a) (b)

Figure - 6: Total deformation of deck panel (a) Al alloy (b) AMMC (Case 1)

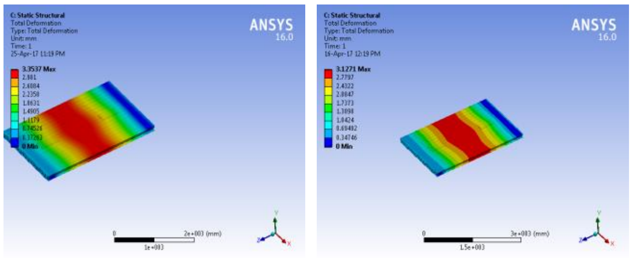


Figure - 7: Total deformation of deck panel (a) Al alloy (b) AMMC (Case 2)

Table-4:comparison of deformation of AMMC and Al alloy deck panel-

Load Case	Material	Applied factored load(kN)	Single span deflection mm	Span/deflection ratio
Case 1	AMMC	83	2.90	1000
	Al alloy	83	3.12	929.4
Case 2	AMMC	166	3.12	929.4
	Al alloy	166	3.35	865.67

Deformation of AMMC and Al alloy are listed in table 4. The maximum deflection induced in the deck panel of aluminium alloy is 3.35 mm and maximum deflection of AMMC deck panel is 3.12 for the load case 2. The deflection of model for case 1 & case 2 load cases met the limit specified by journal[5], thereby showing that the total deflection caused by dead load, live load, and impact was less than 1/500 of the span.

4. CONCLUSIONS

Aluminium metal matrix composite was developed for deck panel and its properties were compared with alloy 6061 .Based on study the properties like hardness, tensile strength ,Impact strength, it can be concluded that aluminium metal matrix composite is superior to alloy 6061. Deformation of aluminium metal matrix composite bridge deck panel was compared with that of Al alloy 6061 bridge deck panel under IRC Class A , which lead to the inference that aluminium metal matrix composite panel has lesser deformation than Al alloy 6061 panel for all loading conditions.

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