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Development and Testing of Nano-Clay Composites for Pressure Pad Application

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ABSTRACT:

Pressure pads are used in mobile cranes and launch vehicles to distribute the reaction forces uniformly on the soil. In mobile cranes these pressure pads made on alloy steel and permanently fixed below the elephant foot through ball and socket joint. Launch vehicles are used to carry and outrigger the missiles in operating field or war field. Load distribution during the outrigger will be challenging in uneven ground surfaces and loose soils. Pressure pads add the flexibility in outriggering the missiles even in a loose soil with ground pressure of 4kg/cm^2. Considering the place of application, detachable type pressure pads are used in launch vehicles. Aluminium alloy is preferred over the steel due to its less weight and easy handling. In this research study nano-clay epoxy composites are proposed as an alternate material for pressure pads of launch vehicles due to its high compression load and strength to weight ratio. The present study focused on the preparation of nano-clay epoxy composites and neat epoxy composites. The work further analyzed the deflection of composites during forward and reverse loading. Creep test was also conducted for a period of 4 hours. The test results revealed that the nano-clay composites were bearing more compressive strength with lesser weight than neat resin composites.

KEYWORDS:

Pressure pad; Epoxy nano-clay composites; Neat epoxy composites; Deflection test; Creep test

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1. Introduction

Launch vehicles are used to carry and outrigger the missiles in operating field or war field. Load distribution during the outrigger of launch vehicles will be challenging in uneven ground surfaces and loose soils. Pressure pads are used to distribute the reaction forces uniformly on the soil. Pressure pads add the flexibility in outrigger the missiles even in a loose soil with ground pressure of 4kg/cm^2. Considering the place of application, detachable type pressure pads are used in launch vehicles. To develop light weight epoxy clay nano pressure pad having high potential in taking compression loads, reduction of weight is one of major area of development. Yasmin et al [1] had studied the compounding of clay/epoxy nano composites based on intercalation/ exfoliation. The compounding process was carried out with varying mixing time and concentrations of clay particles (1 to 10% wt.). Three-roll mill machine was used to disperse/exfoliate the nano-clay particles in an epoxy matrix. To characterize the mechanical properties of the nano composites, XRD and TEM were used. The results revealed that longer the mixing time, the higher the degree of intercalation. Increase clay content, increase the elastic modulus. The compounding of clay/epoxy nano composites by a three-roll mill was resulted higher levels of intercalation/exfoliation compared with conventional direct and solution mixing techniques. Tian et al [2] had investigated the effect of strain-rate in compressive properties of the highly cross-linked epoxy and the epoxy samples. The epoxy-based nano composite and neat epoxy samples were prepared by mixing the Nanopox E470 with an appropriate amount of the aforementioned epoxy resin at a rotation speed of 4000rpm for 1 hr in a heated oil bath of 100°C.

Compression test at various strain rates were carried out. The results revealed that the compressive modulus and transition strength of both samples increased with increase in strain. Also it’s found that adding the sol-gel-formed silica nano particles can improve the compressive modulus, transition strength and strain energy. Ayatollahi et al [3] had studied the effect of concurrent presence of multi-walled carbon nano tubes (MWNT) and nano-clay on the electrical and mechanical properties of epoxy composites. The SEM micrographs were used for the fractography of specimens and investigation of the dispersion state of MWNTs in the matrix. The X-ray diffraction (XRD) was used to determine the d-spacing of nano-clay layers. The study revealed that the nano composite reinforced with 0.5wt% MWNTs have higher modulus compared with a nano composite enhanced with 5wt% nano-clay and higher Young's modulus can be achieved by lower content of MWNTs. Also found that the electrical conductivity can be achieved by adding MWNTs.

Wang et al [4] had investigated for epoxy/clay nano composites. Slurry-compounding process used for preparation. The microstructures of the nano composites (epoxy/s-clays) were characterized by means of optical microscopy and transmission electron microscopy (TEM). The results revealed that clay was highly exfoliated and uniformly dispersed. Also found that the increase in clay concentration increases the Young's modulus and maximum fracture toughness achieved at 2.5wt % of clay. There is no change in R-curve behaviour. Most of the micro cracks initiate between clay layers. The initiation and development of micro cracks are the dominant micro deformation and fracture mechanisms in the epoxy/ S-clay nano composites. After careful analysis of various research studies conducted so far it has been found that sufficient literature review was not available for epoxy clay nano pressure pads for higher application of compression loads. To overcome the limitations of the existing technologies in the field of pressure pads epoxy nano pressure pad is prepared having advantages of high strength-to-weight ratio and high rigidity, lighter in weight by 1.8 to 6 times lesser compared to aluminium/ steel.

2. Test samples preparation

3.1. Epoxy nano-clay composite preparation

Epoxy nano-clay material was prepared by mixing 1% of nano-clay with 99% of epoxy resin. The viscosity of resin is reduced by preheating the mixture about 20 minutes. Sonication was done for 2 hours to ensure proper mixing of nano-clay. Mechanical stirring at 200rpm, as shown in Fig. 1, was done for 30 minutes then the mixture was kept in fridge for 10 minutes to reduce the solution temperature by 10°. Since exothermic reaction (breakdown of solution) occurs after mixing of hardener to the nano epoxy mixture, the hardener is added by mechanical stirring at 200rpm.

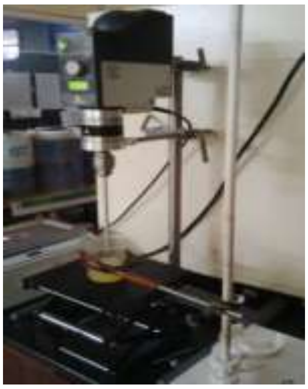

Fig. 1: Mechanical stirrer

3.2. Neat epoxy composite preparation

Neat epoxy resin is preheated for about 20 minutes to reduce its viscosity. Then 40g hardener is slowly added into it and stirred for 10 minutes. The mould releasing agent is applied to the mould cavity and then the mixed neat resin is poured in to the moulds until the solution has settled down. Fig. 2 shows the moulds and mixed neat resin. Curing is done at room temperature for a period of 12 to 16 hours.

Fig. 2: Mould

Rectangular blocks and cylinders were generally used shapes of testing specimens. As per ASTM D 695 standard, the following sample dimensions were cut:

- Rectangular block - 12.7×12.7×25.4mm (Fig. 3).
- Cylinder specimen size - 12.7mm in dia. and 25.4mm long (Fig. 4).

A per ISO, the preferred specimens were 50 x 10 x 4mm for modulus and 10 x 10 x 4mm for strength.

Fig. 3: Rectangular block specimen

Fig. 4: Cylindrical specimen

3. Testing procedure

Prepared sample specimens were examined for compressive test initially. The width and thickness of the specimen are measured with the accuracy of 0.01mm (0.001in.) at many places along its length. Based on the measured dimensions, the minimum value of the cross-sectional area and the specimen length are calculated and recorded. The test specimen is placed between the surfaces of the compression tool as shown in Fig. 5. The axial alignment and parallelism of the specimen's top and bottom surfaces are ensured. The crosshead of the testing machine is adjusted until it just contacts the top of the compression tool plunger as shown in Fig. 6. In order to find the compressive strength, the crosshead speed control is set at 1.3mm/min and the maximum load carried by the specimen during the test (usually this will be the load at the moment of rupture) is checked.

Fig. 5: Compressive test specimen grid pattern

Fig. 6: Compressive test rig

Epoxy nano-clay and neat epoxy samples are prepared and machined to maintain the dimensions uniformly for the tests. Test jig is especially designed for checking the validation of electro mechanical outrigger jacks (EMO) at operating load. The test jig is fabricated to mount the outrigger jacks. A load cell is positioned at the bottom of jack where the compressive loads can be measured. The EMO jacks are designed to withstand maximum load of 20tons. The EMO jacks in the system fitted are supported with pressure pad. These pressure pads are designed to take soil pressure of 4kg/cm^2.

4. Results and discussion

Compressive tests were carried out in cylindrical specimen of neat epoxy and epoxy nano-clay composites separately and the results are shown in Tables 1 to 5. Comparisons were made to know that the neat epoxy and nano-clay epoxy were capable to use as alternative material. The experimental results revealed that neat epoxy has failed to retain the deformation after subjected to compressive loads. Creep test revealed that the epoxy nano-clay composites were retained their original dimensions after the test. The experimental study concludes that addition of nano particle increases the compression strength as well increase the elasticity by retaining their original size after the removal of load.

Table 1: Compressive test results – Cylindrical specimen

Nano-clay composites				Neat epoxy composite			
Dia. (mm)	Area (mm^2)	Load (kN)	Comp. strength (MPa)	Dia. (mm)	Area (mm^2)	Load (kN)	Comp. strength (MPa)
13.16	135.951	12.68	93.27	13.25	137.817	11.23	81.49
13.2	136.778	12.03	87.95	13.2	136.778	12.28	89.78
13.2	136.778	12.47	91.17	13.16	135.951	12.29	90.40
13.22	137.193	12.5	91.11	13.23	137.401	12.05	87.70
		Mean	90.88			Mean	87.34

Table 2: Rectangular block specimen results

Nano-clay composites						Neat epoxy composite					
Sample No.	Initial length (mm)	Initial width (mm)	Initial height (mm)	Final height (mm) after 1st iter'n	Final height (mm) after 2nd iter'n	Sample No.	Initial length (mm)	Initial width (mm)	Initial height (mm)	Final height (mm) after 1st iter'n	Final height (mm) after 2nd iter'n
S1	38	29.7	10.4	10.4	10.4	S1	38	29.7	10.4	10.3	10.2
S2	38	29.7	10.4	10.4	10.4	S2	38	29.7	10.4	10.3	10.2
S3	38	29.7	10.4	10.4	10.4	S3	38	29.7	10.4	10.3	10.2
S4	38	29.7	10.4	10.4	10.4	S4	38	29.7	10.4	10.3	10.2
S5	38	29.7	10.4	10.4	10.4	S5	38	29.7	10.4	10.3	10.2

Table 3: Load vs. Deflection - forward and reverse loading (1st iteration)

Nano-clay composites				Neat epoxy composite			
Forward load		Reverse load		Forward load		Reverse load	
Load (T)	Deflection (mm)	Load (T)	Deflection (mm)	Load (T)	Deflection (mm)	Load (T)	Deflection (mm)
0	0	20.0	1.75	0	0	20.0	1.62
1.07	0.2	19.13	1.69	1	0.25	19.13	1.59
2.1	0.35	18.00	1.6	2	0.3	18.00	1.52
3.13	0.44	17.13	1.53	3.01	0.43	17.13	1.48
4	0.51	16.14	1.44	4.01	0.52	16.14	1.41
5	0.6	15.02	1.36	5.05	0.6	15.02	1.33
6.17	0.69	14.02	1.28	6.02	0.67	14.02	1.28
7	0.75	13.11	1.20	7.02	0.81	13.11	1.22
8	0.83	12.07	1.12	8	0.81	12	1.14
9	0.9	11.05	1.05	9.07	0.83	11.02	1.09
10	0.98	10	0.98	10.02	0.95	10.03	1.01
11	1.05	9.05	0.9	11.01	1.01	9	0.96

Table 3 (Contd.): Load vs. Deflection - Forward and reverse loading (1st iteration)

Nano-clay composites				Neat epoxy composite			
Forward load		Reverse load		Forward load		Reverse load	
Load (T)	Deflection (mm)	Load (T)	Deflection (mm)	Load (T)	Deflection (mm)	Load (T)	Deflection (mm)
12.04	1.12	8.01	0.83	12.07	1.08	8.07	0.89
13.02	1.2	7.08	0.75	13.10	1.15	7.00	0.82
14.03	1.28	6.06	0.68	14.04	1.22	6	0.75
15	1.36	5.02	0.6	15.09	1.29	5.02	0.68
16.08	1.44	4.07	0.51	16.07	1.36	4.07	0.62
17.01	1.52	3.03	0.44	17	1.42	3.03	0.54
18.03	1.6	2.04	0.34	18.02	1.5	2.04	0.46
19	1.68	1.05	0.2	19.08	1.56	1.05	0.35
20	1.75	0	0	20.01	1.62	0	0.10

Table 4: Load vs. Deflection - Forward and reverse loading (2nd iteration)

Nano-clay composites				Neat epoxy composite			
Forward load		Reverse load		Forward load		Reverse load	
Load (T)	Deflection (mm)	Load (T)	Deflection (mm)	Load (T)	Deflection (mm)	Load (T)	Deflection (mm)
0	0	20	1.59	0	0	20.01	1.55
1.11	0.009	19	1.52	1	0.22	19.05	1.5
2.06	0.19	18	1.45	2.06	0.32	18.06	1.45
3.01	0.27	17.04	1.37	3.10	0.41	17.03	1.39
4	0.37	16.01	1.31	4	0.5	16.06	1.31
5	0.46	15	1.23	5.05	0.56	15	1.26
6	0.55	14.01	1.15	6.02	0.62	14	1.20
7.01	0.62	13	1.08	7.01	0.7	12.96	1.12
8.03	0.7	12	1.01	8.14	0.78	12.07	1.08
9.01	0.78	11	0.93	9.05	0.83	11.05	1.01
10.09	0.86	10	0.85	10	0.88	10	0.95
11	0.93	9	0.78	11	0.95	9.05	0.89
12	1.01	8	0.7	12	1.02	8.01	0.82
13	1.08	7	0.62	13.01	1.09	7.08	0.76
14.01	1.16	6	0.55	14.08	1.15	6.06	0.69
15	1.23	5	0.46	15	1.21	5	0.62
16.01	1.3	4	0.38	16.01	1.29	4	0.55
17.04	1.37	3	0.27	17.08	1.36	3.10	0.48
18	1.45	2	0.2	18	1.42	2	0.39
19	1.52	1	0.009	19.03	1.49	1.02	0.28
20	1.59	0	0	20.01	1.55	0	0.10

Table 5: Creep test - Load vs. Deflection of nano-clay epoxy samples (4 hours)

Load (T)	Deflection (mm)	Time in duration of 15 min.	Load (T)	Deflection (mm)	Time in duration of 15 min.	Load (T)	Deflection (mm)	Time in duration of 15 min.
20	1.75	0	19.51	1.87	90	19.61	1.91	180
19.76	1.82	15	19.55	1.88	105	19.61	1.91	195
19.65	1.85	30	19.60	1.90	120	19.61	1.91	210
19.60	1.85	45	19.61	1.91	135	19.61	1.91	225
19.60	1.85	60	19.61	1.91	150	19.61	1.91	240
19.52	1.86	75	19.61	1.91	165	19.61	1.91	255

5. Conclusion

In launch vehicles, to distribute the reaction forces uniformly on the soil, pressure pads are used. The present study focused on the preparation of nano-clay epoxy composites and neat epoxy composites. Compressive tests had revealed that the neat epoxy composites were having less compression strength compared with nano-clay epoxy composites. Load and creep tests confirm that the deformation and elasticity properties of nano-clay epoxy qualifies for the proposed application.

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