FATIGUE ANALYSIS ON GLUED STEEL BAR CONNECTORS FOR LOG – CONCRETE COMPOSED DECK BRIDGES

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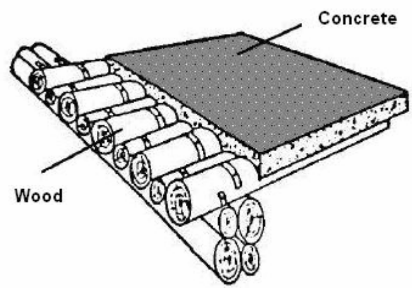
Abstract. *The log-concrete composed deck bridges with steel bars connectors is an important alternative for small and medium spans. These kind of bridges seem to be a economic and safety structure in Brazil. The aim of this work is the experimental analysis of fatigue behavior of glued steel bars used as connector element in log-concrete composed deck bridges. Static and dynamic tests were carried out in order to evaluate the fatigue of the connector using two species of reforestation wood, three types of adhesives and three levels of wood moisture content. The main failure fatigue modes are presented. The results shows a good performance of the epoxi glue steel bar connector for use in log-concrete composed dek bridge.*

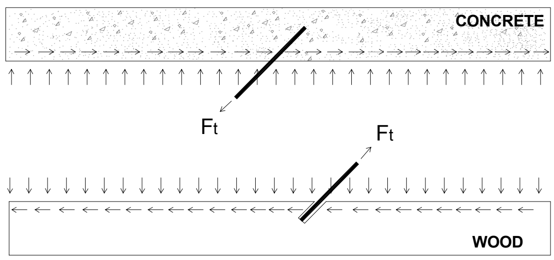
Keywords: *Bonded-in steel rods, Shear connections, Fatigue, Structural adhesives*

1. INTRODUCTION

The association of the wood-concrete materials in the construction of log–concrete composite deck bridges results in elements with excellent structural characteristics, combining the best in each material. However, it is fundamental the use of a connection system so that both materials work together. A connection system used to join the materials timber-concrete is the glued steel bars, for presenting low cost and easy execution. In Brazil, don't have regulamentations related to the use of glued steel bar connectors in wood specimens, although they have been used for more than twenty years at some Scandinavian countries and in Germany. This paper presents the results of experimental investigation in the relation fatigue behavior, considering the use of commercial adhesives to bond threaded steel rods into oversized holes in order to achieve structural timber connections for log-concrete composed deck bridges.



a) Log–concrete composite deck bridge



b) Glued steel bar connector – interface of the materials

Figure 1. Connection system between wood-concrete

2. EXPERIMENTAL PROGRAMME

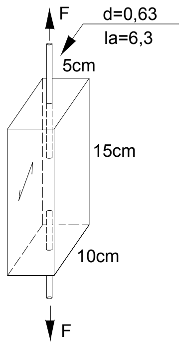
Three types of adhesives have been considered in this fatigue study: two epoxy adhesives (Sikadur 32 and Compound Adhesive) and a PUR adhesive (Purweld 665). The number of cycles to failure and mode of failure have been examined for one geometry of test specimen and for one diameter of bar, as described in Table 1.

Table 1. Static and fatigue test specimens.

Test Series	01	02	03
Species of wood	*Euclyptus Citriodora*	*Pinus Taeda*	*Pinus Taeda*
Moisture Content (%)	12 17 22	12 17 22	22
Bar Diameter (mm)	6.3	6.3	6.3
Diameter of hole (mm)	7.9	7.9	7.9
Anchorage Length (cm)	6.3	6.3	6.3
Adhesive	(Epoxy) Sikadur and Compound	(Epoxy) Sikadur and Compound	(PUR) Purweld 665

2.1. Description of Tests

Initially, in the determination of the parameters to be used in the fatigue tests, the specimens were loaded statically at 0,10kN/seg until failure. The static tests were accomplished in two load cycles. The first cycle was accomplished with load of 50% of the ultimate strength of the connection, and the second cycle, with applied load until the failure of the connection. For each case, were registered the type of failure mode, for each moisture content and adhesive type applied. Fig. 2 shows the static and fatigue tests configuration with bonded rods fixed at angle 45º to the grain, and loaded axially.



a) Test configuration

b) Test in process

Figure 2. Fatigue and static tests

Bonded-in steel rod specimens were exposed to 1x 10^6 load cycles, with constant-amplitude, sinusoidal fatigue cycles at a frequency of approximately 5Hz. Fig. 3 shows the fatigue parameters, used in the fatigue tests, with three force levels related with ultimate strength static, using cyclic axial tension fatigue (R=0,1).

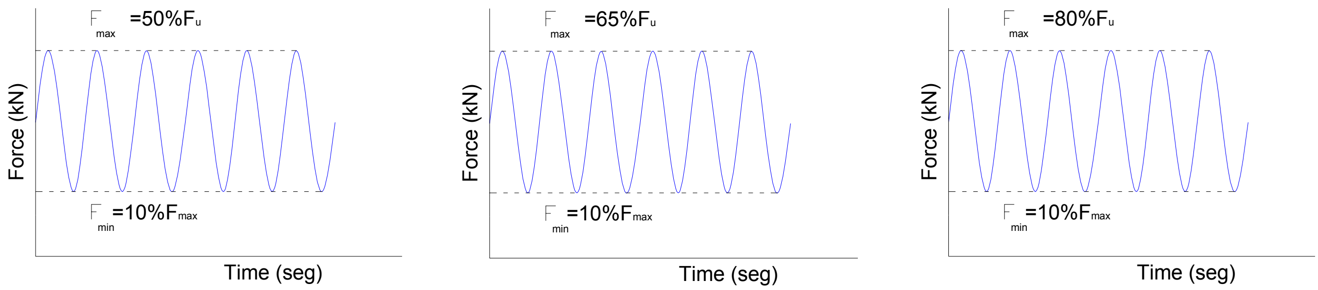
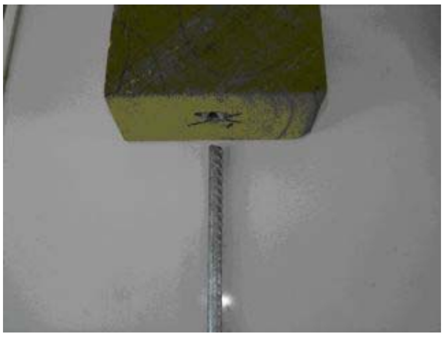


Figure 3. Fatigue test parameters

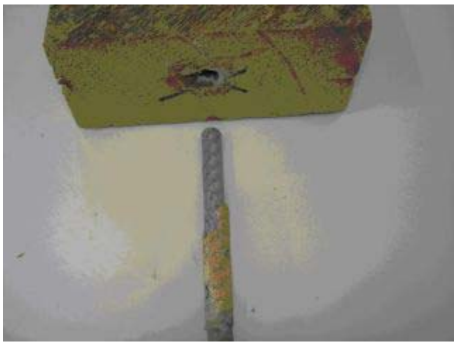
3. RESULTS

Six distinct failure modes were observed through the fatigue tests: a) Rod interface failure; b) Timber interface failure; c) Timber interface/rod interface composed failure; d) Rod interface/timber substrate composed failure; e) Rod failure and f) Failure in the adhesive. Fig. 4 shows these fatigue failure modes.

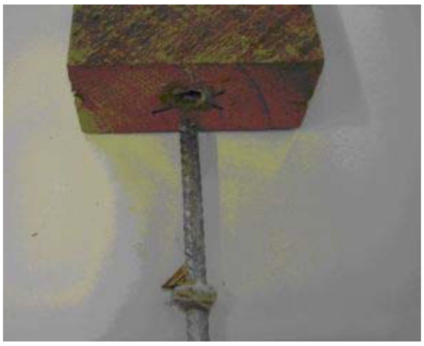


a) Rod interface failure
(Sikadur)

b) Timber interface failure
(Compound)



c) Timber interface/rod interface composed failure
(Compound)



d) Rod interface/timber substrate composed failure
(Sikadur)

e) Rod failure
(Sikadur)

f) Adhesive Failure
(Purweld 665)

Figure 4. Different failure modes observed in fatigue tests.

Table 2. Failure modes observed through fatigue tests - *Pinus Taeda*

Adhesive	Failure modes					
	(a)	(b)	(c)	(d)	(e)	(f)
Sikadur	*			*	*	
Compound	*		*			
Purweld 665						*

Table 3. Failure modes observed through fatigue tests - *Eucalyptus Citriodora*

Adhesive	Failure modes					
	(a)	(b)	(c)	(d)	(e)	(f)
Sikadur	*				*	
Compound		*	*		*	

Table 4. – Ultimate strength (kN) of the connection - Static tests

Adhesive	*Pinus Taeda*			*Eucalyptus Citriodora*		
	U=12%	U=17%	U=22%	U=12%	U=17%	U=22%
Sikadur	3.71	2.91	2.33	5.76	5.44	4.03
Compound	2.02	1.99	1.53	3.45	1.99	1.80
Purweld 665	-	-	0.97	-	-	-

3.1. Graphs of fatigue

The data obtained from the fatigue tests at R = 0.1 (i.e. maximum tensile load = 10 x minimum tensile load), illustrating the performance of each specimen, are presented in the form of cycles to failure in Fig 5 to Fig 8. The area considered for the traverse section of the bars of steel was 0.31 cm^2 (diameter of bar = 6.3 cm).

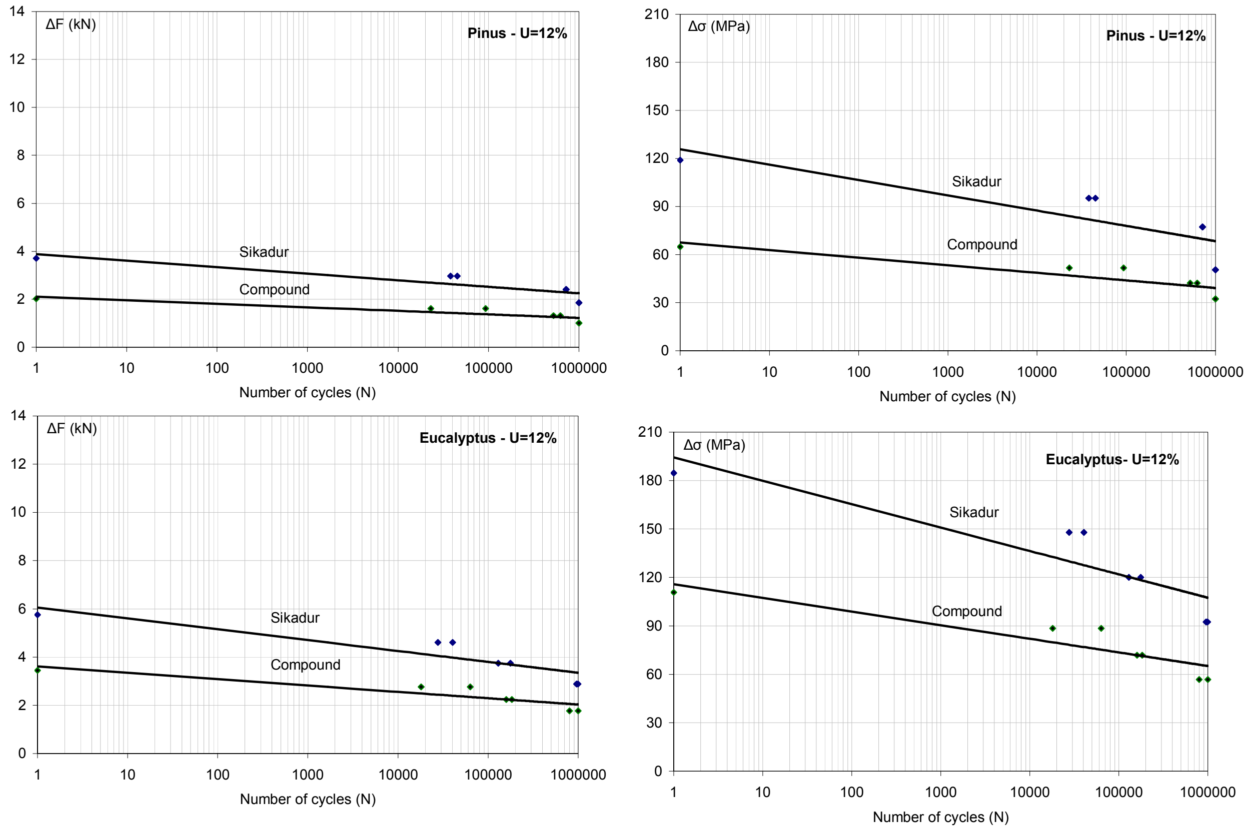


Figure 5. Fatigue performance for the epoxy adhesives – Moisture = 12%

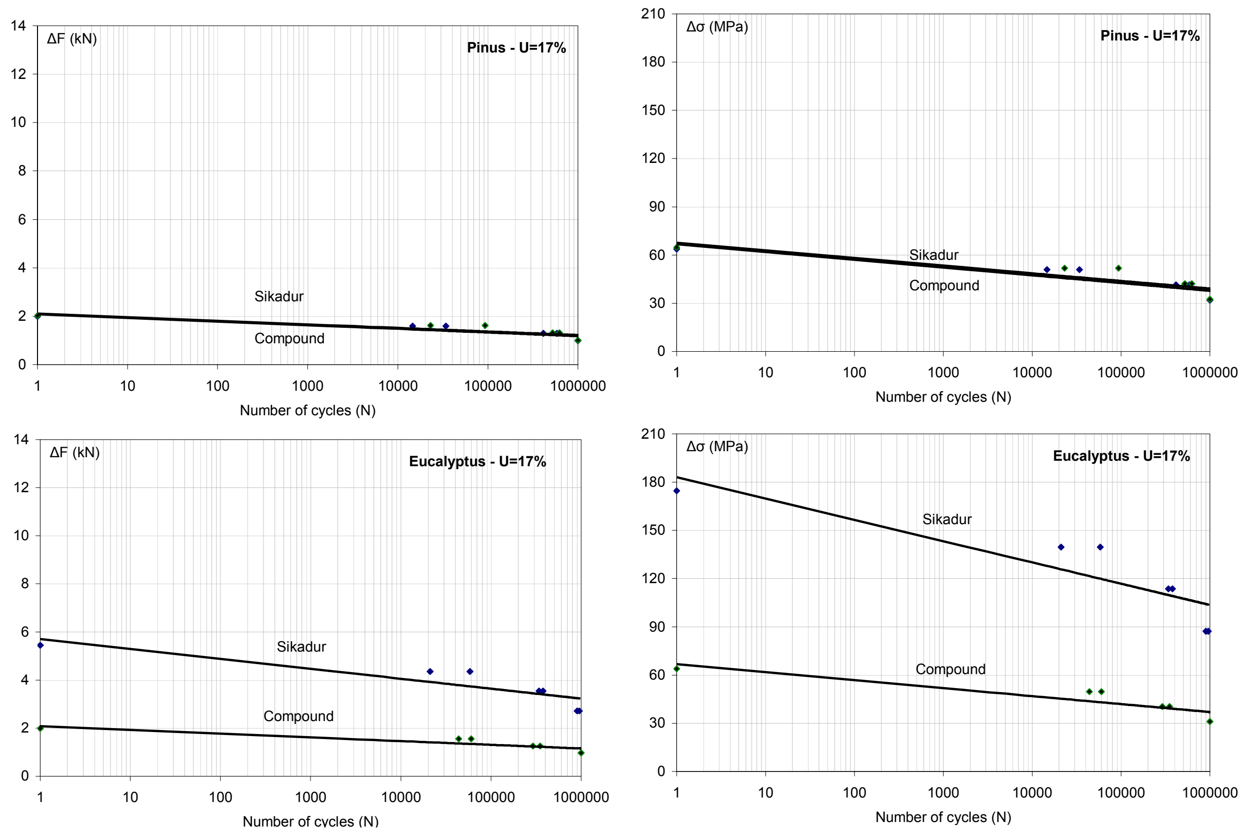


Figure 6. Fatigue performance for the epoxy adhesives – Moisture = 17%

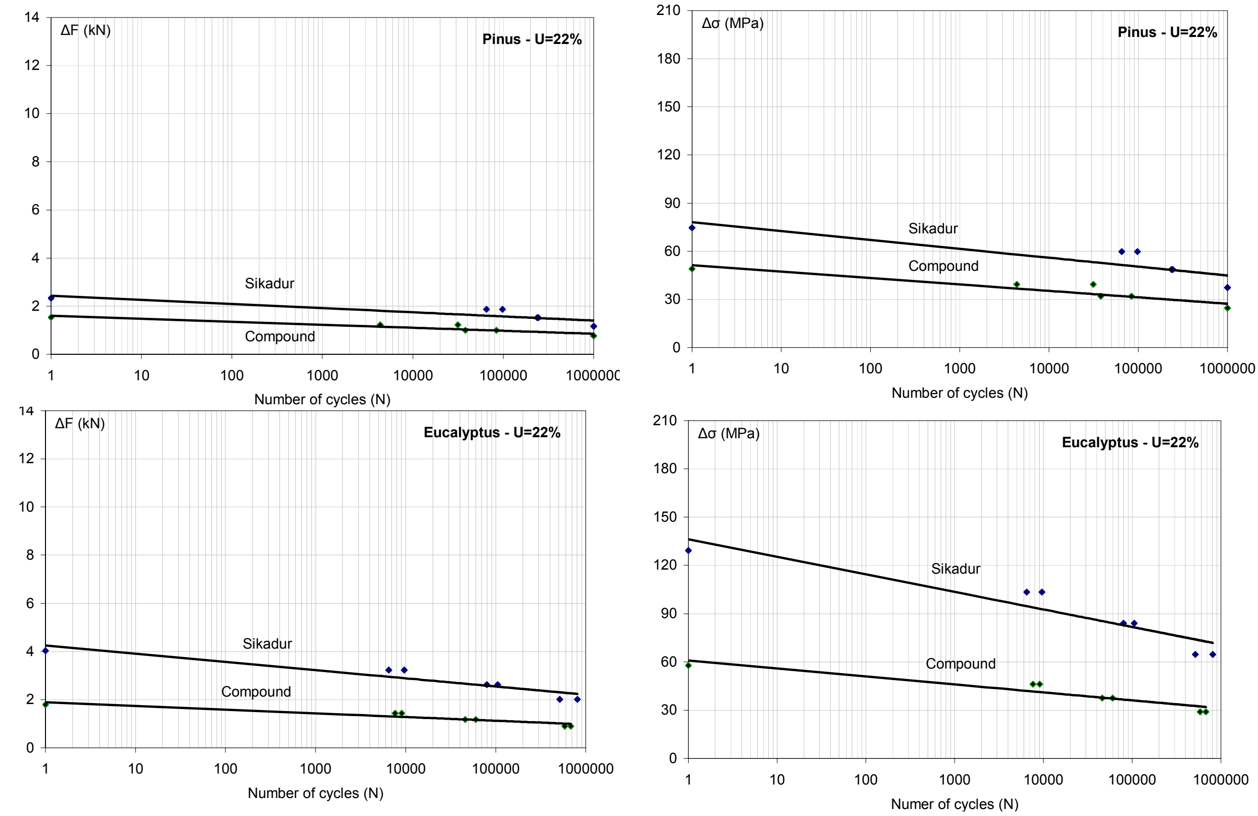


Figure 7. Fatigue performance for the epoxy adhesives – Moisture = 22%

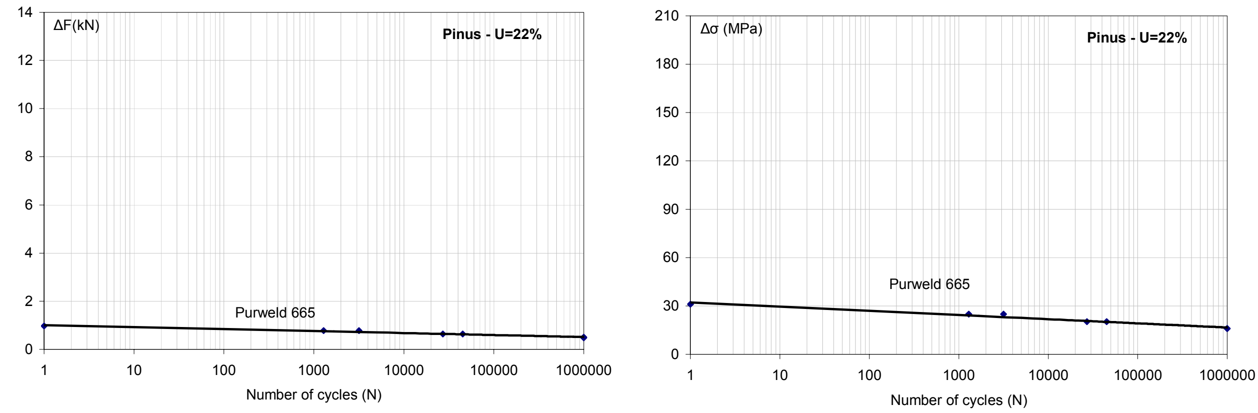


Figure 8. Fatigue performance for the PUR adhesive – Moisture = 22%

4. CONLUSIONS

The results of fatigue tests showed that the specimen of *Eucayptus Citriodora* presented larger strength of anchorage than specimen of *Pinus Taeda*. The behavior of fatigue is affected by the moisture content and type of adhesive used. Usually, larger moisture contents for bonded-in rods in specimens lead to smaller anchorage strength for the steel bar. The epoxy adhesive presented excellent glued behavior to both steel and wood for the moisture contents analyzed: 12%, 17% and 22%. The PUR adhesive is not indicated for bonded-in rods in specimens of wood, because the surface of PUR adhesive often contains CO_2 bubble formation at the bond causing a reduction in the effective cohesion. This is the result of reaction of the adhesive components with moisture in timber. The fatigue failure can happen in any of the component materials: steel rod, adhesive, or the timber. The behavior of fatigue presented a recognized impact damaging mainly the bar of steel. There is a potential risk of fatigue failure in the bonded-in rods. Except the rod failure, the fatigue failure modes are relatively consistent with static test observations. The strength at 10^6 cycles (with R=0,1) as compared to the first cycle strength in tension represents 50% of strength reduction.

5. REFERENCES

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