# Fatigue resistance of wood-fiberglass composite materials

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***Abstract.*** *This article presents the results of endurance tests of fiberglass composite material based on polyester resin. Low-cycle fatigue tests were carried out on machines GRM-2A and IP 5113-100 in accordance with the regulatory documentation. The equations of the empirical line of endurance are presented.*

***Keywords:*** *polyester resin, composites, material fatigue, railway sleepers.*

The process of gradual accumulation of localized damage when exposed to a time-varying load is called fatigue. The ability of a material or structure to resist fatigue is called endurance.

Distinguish between high-cycle and low-cycle, static and physical fatigue, depending on the power loading conditions [1].

Multicycle fatigue of DSVKM was investigated in the works of V. I. Kharchevnikov, O.P. Pluzhnikova and B. A. Bondarev [2, 3]. They proved that the material under study possesses sufficient endurance for its use in structural elements of railway sleepers [4].

With prolonged exposure to loads, the loading steps of the samples in terms of conditional stresses were taken to be 24.5; 33.0; 54.0; 63.0; 73.0; 83.0 and 93.0 MPa. Based on the test results, the creep curves of the specimens in bending were constructed and the boundaries of the possible value of the long-term strength (33 MPa < $R_{B,inf}$ < 54 MPa) were determined. According to a well-known technique, the duration coefficients were calculated and the curves of the change in bending strength over time were constructed, and from them the duration coefficient was determined equal to 0.45.

Physical fatigue or the ability to resist various temperature and humidity influences was also reflected in the works of A.S. Prokofiev, V.A. Kabanov, A.A. Smorchkov [5].

Studies of long-term strength under the simultaneous action of liquid media and long-term bending load were carried out on samples - plates containing 3% longitudinal fiberglass reinforcement (by weight) and 2% - transverse (fiberglass mesh). Plate dimensions 320x180x10 mm. The initial strength at "pure bending" was 48 MPa, the instantaneous modulus of elasticity was $0.6*10^4$ MPa. Samples – plates were immersed in water and loaded using a special device that allows, by changing the levers and applying various combinations of weights, to create conditional stresses of 0.2 in the zone of "pure" bending of the samples; 0.3; 0.4 and 0.5 of the average ultimate strength in bending - 48 ... 50 MPa. The test results showed that the limits of the possible value of the long-term strength for accepting the percentage of reinforcement are 20 and 25 MPa. The coefficient of duration, taking into account the action of an aggressive environment, was determined using the structural diagram of A. M. Ivanov [6] and its value was 0.46. The studies carried out have established the presence of long-term strength not only in an ideal environment, but also under the action of an aggressive environment.

Low-cycle fatigue of fiberglass composite material has not been studied until now. Since the collapse of the USSR, the production of furfural acetone monomer (FAM) in the Russian Federation has not been restored. On the other hand, the industry for the production of polyester resins of various grades began to develop dynamically, in connection with this, the development of new compositions for polymer solutions, which are a matrix for the production of sleepers and their resistance to fatigue to variable loads, has become a topical trend.

For tests, prisms with dimensions of 100x100x400 mm and 40x40x160 mm were made from the composition shown in table 1.

Table 1 - Composition of polymer concrete mixture.

| № | Components | Content, kg per $m^3$ |
|---|---|---|
| 1 | Polyester resin Holex HAS 2061 | 275 |
| 2 | Hardener (to resin Holex HAS 2061 ) | 5,5 |
| 3 | Sand medium Mk=2…2.5 mm | 610 |
| 4 | High quality microsilica MK-85 | 82.39 |
| 5 | Wood shavings (softwood) | 354 |

The characteristics of the above binder are shown in table 2.

Table 2 – Characteristics of Holex HAS-2061 polyester resin.

| Properties | Indicator | Units | Method |
|---|---|---|---|
| Appearance | Transparent yellow liquid with slight opalescence | | Visual |
| Gelation time, at 20°C 2% (MEKP-50) | 20-30 | min | DUGALAK technique |
| Brookfield dynamic viscosity RV at 23ºC, speed 12, spindle 3 | 700-800 | mPa*s | GOST25271-93 ISO 2555-89 |
| Flash point | 31 | ºC | ISO 3679 |
| Density | 1.13 | kg/m$^3$ | ISO 2811-2001 |
| Styrene content | 31-35 | % | GOST13549-78 |

Endurance tests of DSVKM in bending with a matrix based on Holex HAS-2061 polyester resin were carried out on an IP 5113-100 testing machine with a load frequency of 670 cycles/minute with a cycle asymmetry coefficient $\rho = 0{,}1$. A total of 6 elements were tested. The test results are shown in table 3.

Table 3 – High cycle fatigue test results $\rho = 0{,}1$.

| № of beam | Breaking bending moment $M_p$(H*m) | Deviation from the mean, $M_p$ | Squared deviation | Cycles to failure, N | $lgN$ | Deviation from the mean | Squared deviation | Product of deviations |
|---|---|---|---|---|---|---|---|---|
| P1 | 1.55 | 0.402 | 0.162 | 72720 | 4.849 | - 0.880 | 0.776 | - 0.354 |
| P2 | 1.35 | 0.202 | 0.0408 | 170700 | 5.234 | - 0.496 | 0.246 | - 0.0202 |
| P3 | 1.14 | - 0.008 | 0.000064 | 452620 | 5.653 | - 0.246 | 0.0605 | + 0.00197 |
| P4 | 1.00 | - 0.148 | 0.0219 | 911860 | 5.959 | + 0.229 | 0.0524 | - 0.0338 |
| P5 | 0.95 | - 0.198 | 0.0392 | 1851200 | 6.262 | + 0.532 | 0.283 | - 0.1054 |
| P6 | 0.90 | - 0.248 | 0.0615 | 2660510 | 6.423 | + 0.693 | 0.480 | - 0.1584 |
| | $M_p^{av}$ =1.148 | | $\Sigma$= -0.325 | | $lg^{av}N$ | | $\Sigma$= 1.898 | $\Sigma$= - 0.669 |

At $\rho = 0.1$ the equation of the empirical line of endurance is written as follows:

$$M_{pul}^{p} = 3{,}333 - 0{,}381 lgN \ , \qquad (1)$$

where $M_{pul}^{p}$ - destructive bending moment (endurance limit of DSVKM), $N$ - the number of load application cycles before failure.

Low-cycle fatigue tests were carried out with an asymmetry coefficient of the load application cycle at $\rho$ = 0.1 on a GRM-2A testing machine in accordance with GOST 24545-81. Concrete. Endurance test methods. A total of 6 samples were tested. The results of their tests are shown in table 4.

Table 4 – Low cycle fatigue test results $\rho = 0{,}1$.

| № of beam | Breaking loads, MPa | Deviation from the mean | Squared deviation | Cycles to failure, N | $lgN$ | Deviation from the mean | Product of deviations |
|---|---|---|---|---|---|---|---|
| P1 | 34.06 | - 5.56 | 30.914 | 5.290 | 0.814 | 0.663 | - 4.526 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| P2 | 35.50 | - 4.12 | 16.974 | 4.969 | 0.493 | 0.243 | - 2.031 |
| P3 | 39.06 | - 0.56 | 0.314 | 4.225 | - 0.251 | 0.063 | +0.141 |
| P4 | 41.61 | 2.99 | 8.940 | 4.105 | - 0.371 | 0.138 | - 1.109 |
| P5 | 42.3 | 5.89 | 24.528 | 3.968 | - 0.462 | 0.276 | - 0.358 |
| P6 | 45.86 | 7.24 | 52.418 | 3.793 | - 0.683 | 0.466 | - 4.945 |
| | $\sigma_x^{av}$ =39.73 | | $\boldsymbol{\Sigma}\sigma_x^2$=134.09 | $\sigma_y^{av}$=4.39 | | $\boldsymbol{\Sigma}\sigma_y^2$=1.85 | $\boldsymbol{\Sigma}$= - 12.828 |

The equation of the empirical line of endurance for the DSVKM of the adopted composition under compression will be written as follows:

$$R_{v,pul}^{min}=74.74-7.86 lgN . \qquad (2)$$

Thus, the results of studies of DSVKM on Holex HAS-2061 polyester resin show that this material has sufficient cyclic durability under repeated and repeated loading. Studies on static and physical fatigue are nearing completion.

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