THE SUSTAINABILITY OF SOME REHABILITATION SOLUTIONS FOR A PRESTRESSED CONCRETE METHANE TANK

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ABSTRACT
The paper deals with the rehabilitation solutions for a methane tank and the sustainability aspects of the rehabilitation. The rehabilitation solutions for the methane tank are partial wrapping with CFRP and GFRP fabrics. The rehabilitation sustainability is evaluated with a relationship for calculating the index of sustainability. The results reveal that both solutions are advantageous in terms of sustainability.

Keywords: CFRP, GFRP, confinement, consolidation time, cost of rehabilitation, sustainability

INTRODUCTION
Sustainable construction is one of the six markets in the Lead Market Initiative because of its high innovation potential, its capacity to respond to market needs, the strength of European industry and the necessity to support it through the implementation of public measures [1]. It involves environmental concerns, health aspects and issues of convenience. Buildings account for the largest share of the total EU final energy consumption (42%) and produce about 35% of all greenhouse emissions. CO\textsubscript{2} is the main gas responsible for the greenhouse effect. In order to reduce the total CO\textsubscript{2} emission of a structure the phase of its use is going to take more and more importance in its global evaluation as it accounts for 80 to 90% of the total energy consumed throughout its entire lifecycle [2]. The paper deals with the rehabilitation solutions for a methane tank as well as with the sustainability aspects of the rehabilitation.

MATERIALS AND METHODS
1. Degradations and their causes
There are two prestressed concrete methane tanks in Wastewater Treatment Plants Oradea that need rehabilitation.

The main reason for strengthening these tanks is lack of compliance with new code requirements (low concrete strength 11.69 N/mm\textsuperscript{2}, C18/22.5). These tanks are cylindrical structures 10.75 m in height and 19 m in diameter (fig. 1) [3].

The main deficiencies of prestressed concrete tanks are:
- reinforced concrete cracking,
- concrete degradation,
- leakage.
2. Rehabilitation solutions

The rehabilitation solutions proposed for the methane tank are as follow:

- partial wrapping with CFRP fabrics;
- partial wrapping with GFRP fabrics;

Confinement of concrete is an efficient technique to increase the load carrying capacity, strength or ductility of a reinforced concrete member. The main objectives of confinement are [4]:

- to enhance concrete strength and deformation capacities,
- to provide lateral support to the longitudinal reinforcement,
- to prevent the concrete cover from spalling.

These objectives can be achieved by applying external FRP jackets continuously all over the surface or discontinuously as strips.

Fiber reinforced polymer (FRP) composites consist of synthetic or organic high-strength fiber impregnated with a resin matrix.

The use of these materials in strengthening solutions has become an efficient alternative to traditional methods due to some advantages such as their features in terms of strength, corrosion resistance, lightness and ease of application. There is nowadays a wide range of available types of FRP composites (with epoxy, polyester or vinyl-ester matrices) reinforced with carbon, glass and aramid fibers.

CFRP fabrics consist of two components, epoxy-based impregnating resin and carbon fiber fabric and can be used to strengthen reinforced concrete structures or to confine concrete.

GFRP wrap is an unidirectional woven glass fiber fabric for structural strengthening. GFRP wrap can be used for every kind of strengthening requirement. It has an excellent cost performance and it is non-conductive [5].

The CFRP and GFRP dimensions required to provide confinement strengthening and calculated according with FIB Bulletin 14/2001 are:
- SikaWrap Hex 100C: thickness 0.76 mm, width 150 mm, centre-to-centre distance 450 mm, 2 layers (fig. 2),
- SikaWrap Hex 100G: thickness 1.44 mm, width 150 mm, centre-to-centre distance 450 mm, 4 layers (fig. 3).

**Fig. 2. Partial wrapping of the tank with CFRP**

**Fig. 3. Partial wrapping of the tank with GFRP**
3. Economic efficiency

A global quantitative model for evaluating the sustainability is difficult to be produced but for each structural element it may be established [6].

The calculated characteristics of the rehabilitation solutions were:

- the total cost of rehabilitation solution at the level of year 2011,
- the total energy for each solution and consolidation time.

The rehabilitation sustainability was evaluated with a formula (1) proposed by Toadere M. and Bob C. [1].

\[
S = 0.5 \cdot \frac{E}{E_f} + 0.3 \cdot \frac{C}{C_f} + 0.2 \cdot \frac{T}{T_f}
\]  

where:

- \(S\) – the sustainability index of the strengthening solutions,
- \(E\) – the total energy of the strengthening solutions (with GFRP and CFRP),
- \(C\) – the cost of the strengthening solutions (with GFRP and CFRP),
- \(T\) – consolidation time of the strengthening solutions (with GFRP and CFRP).

RESULTS AND DISCUSSIONS

The results obtained for the characteristics of strengthening solutions are presented in Table 1.

<table>
<thead>
<tr>
<th>Strengthening solutions</th>
<th>(E) [kg(\text{CO}_2)]</th>
<th>(C) [RON]</th>
<th>(T) [man-hours]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consolidation with CFRP</td>
<td>741413.14</td>
<td>349995.325</td>
<td>9531.215</td>
</tr>
<tr>
<td>Consolidation with GFRP</td>
<td>735273.09</td>
<td>388049.221</td>
<td>9977.215</td>
</tr>
</tbody>
</table>

When the reference values \((E_f, C_f, T_f)\) are those that result for strengthening with CFRP, the results obtained for the sustainability index were:

\[
S_1 = 0.5 \cdot \frac{741413.14}{741413.14} + 0.3 \cdot \frac{349995.325}{349995.325} + 0.2 \cdot \frac{9531.215}{9531.215} = 1.0
\]

\[
S_2 = 0.5 \cdot \frac{741413.14}{735273.09} + 0.3 \cdot \frac{349995.325}{388049.221} + 0.2 \cdot \frac{9531.215}{9977.215} = 0.97
\]
When the reference values \( (E_f, C_f, T_f) \) are those that result for strengthening with GFRP, the results obtained for the sustainability index were:

\[
S_1 = 0.5 \cdot \frac{735273.09}{735273.09} + 0.3 \cdot \frac{388049.221}{388049.221} + 0.2 \cdot \frac{9977.215}{9977.215} = 1.0
\]

\[
S_2 = 0.5 \cdot \frac{735273.09}{7741413.14} + 0.3 \cdot \frac{388049.221}{34995.325} + 0.2 \cdot \frac{9977.215}{9531.215} = 1.04
\]

Based on the results presented in table 1 we can draw the following observations:

- The total energy of the strengthening solution with CFRP is bigger than the total energy of the strengthening solution with GFRP.
- The cost and the consolidation time of strengthening solution with GFRP are bigger than these characteristics for strengthening solution with GFRP.

The results obtained for the sustainability index show that in terms of sustainability both solutions are advantageous. But the rehabilitation solution with GFRP is more effective than the solution with CFRP in terms of confined concrete strength and ductility as result from a previous paper [3].

CONCLUSIONS

The strengthening solutions with CFRP or GFRP are both effective in terms of sustainability. The differentiation between the rehabilitation solution with CFRP and the rehabilitation solution with GFRP can be made based on the results obtained for confined concrete strength and ductility which reveal that the solution with GFRP is more effective than the solution with CFRP.

The results obtained by the other authors [1] have shown that the rehabilitation solution with CFRP is more advantageous than the classical solutions in terms of sustainability. So the strengthening solutions with FRP are more effective than the classical solutions in terms of sustainability, confined concrete strength and ductility.

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REFERENCES


