

Mixed Wooden-Concrete Piles: A Solution for Structures Located Near Saltwater Lakes

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Abstract. This paper aims to present an ecological solution for creating a long-living structure using wood and eco-friendly concrete. Nowadays, it is an imminent need to reduce the use of non-renewable natural resources and, at the same time, to minimize the negative impacts of waste production from the construction sector. As a result, the option of reusing and reintroducing materials in production cycles in order to form totally different products becomes more common day by day. Even if wood is a hugely capable civil engineering material, the area of untreated pile situated above ground water level is vulnerable. This problem can be found in salty water resorts, as in the case of Oglinzi Baths located in Neamț County. A proper solution for solving this problem could consist of using an already patented concrete that has in composition recycled glass aggregates and, moreover, has outstanding durability properties. This mixed piles structure can be a sustainable alternative benefiting from two commonly used materials and local resources.

1. Introduction

Wood is considered to be a very versatile construction material, with a low weight, very easy to handle and easy to shape. It has also an attractive appearance, low environmental impact and tends to integrate harmoniously into the landscape as it is a natural material. Wood is the only truly sustainable building material. However, the main disadvantage is that, without a protection, all types of wood exposed to weather conditions and in contact with any kind of water are vulnerable to decay [1] because, if they are wholly situated under the water level, their lifetime is extended and remain in perfect condition for centuries. But, if it is watered and dried alternately, it will be destroyed in a short period of time.

Since 1920, engineers have tried to find solutions in order to extend the life of wooden piles and so, they have introduced capping piles, firstly made of wood or stone. After that, concrete was used and it is, by far, the best material for capping wooden piles. It is strong, durable and if it is needed, it can be strengthened by reinforcing with steel [2]. In these conditions, mixed wooden-concrete piles have a lifetime of about 100 years, while wooden piles have a life expectancy of about 20 years [3].

Nowadays, as it is an imminent need to reduce the consumption of non-renewable natural resources and to minimize the negative impacts of waste production from the construction sector, usual concrete needs to be substituted with an already patented eco-friendly concrete. In this context, the construction sector will have to significantly reduce the CO₂ emissions by choosing materials with a low impact and by creating energy-efficient structures.



The main objective of this concrete was to change building practices and integrate ecological alternatives from the design phase. It is one of the most commonly used building material and one of the most “green” options available. Concrete is an important choice for those who want to use eco-friendly materials, as they respond to many environmental responsibility requirements.

The built environment has a substantial impact on energy and material resources, being a determinant factor in terms of health, comfort and occupant productivity. The built sector is one of the greatest consumers of energy (40% of final energy consumption) and responsible for a significant amount of CO₂ emissions (36% of CO₂ emissions) [4].

The development of environmentally friendly new materials should therefore be a permanent concert of researchers in the field. Also, the design of sustainable solutions that allow recycling and recovery of waste as a raw material for obtaining new building material or products should be taken into consideration. In this way, non-renewable, natural resources can be saved [5].

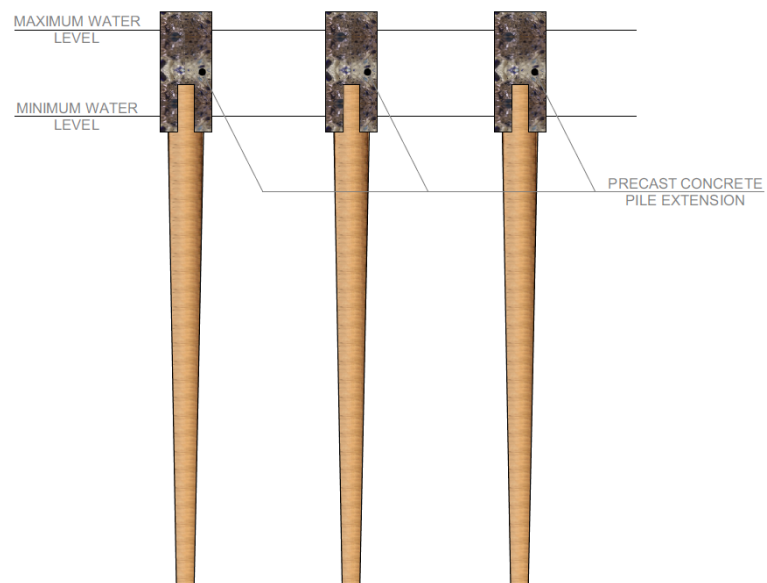


Figure 1. Degraded wooden pile [6]. **Figure 2.** Proposed solution – mixed wooden-concrete piles.

2. Materials and methods

There are two main materials used in this study: wood and eco-friendly concrete.

Wood is considered to be the only renewable material that naturally forms, with real advantages that put it in the top of building materials, being 100% natural and organic. Wooden constructions resist to earthquakes, can be mounted in a short period of time, they are cheap and do not pollute the environment. At the same time, wood is a warm finishing material that can be used inside or outside (using a proper treatment solution) and is a versatile material from an aesthetic point of view [7].

Eco-friendly concrete combines a mixture of constituents like recycled glass aggregates, cement, silica fume, glass powder, admixture and water. According to ACI Committee 363, concrete with superior performance includes the following requirements:

- Ease of putting into operation;
- Long-term mechanical properties;
- High initial resistances;
- Durability;
- Volume stability;
- Long service life under severe environmental conditions [8].

2.1. Materials

The wooden structure was designed using C24 resinous wood with the following composition:

- Wooden circular piles Ø20 cm;
- Wooden beams on two directions, 10x12 cm;
- Wooden floor, h=2.4 cm;
- Connecting elements.

The chosen pilot was the most exposed to heavy load from the platform located above.

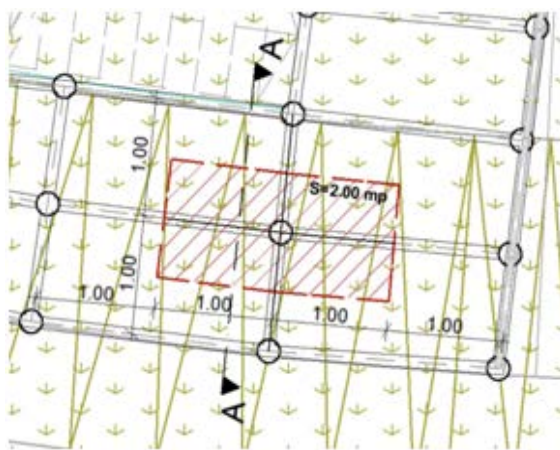


Figure 3. Wooden platform plan.

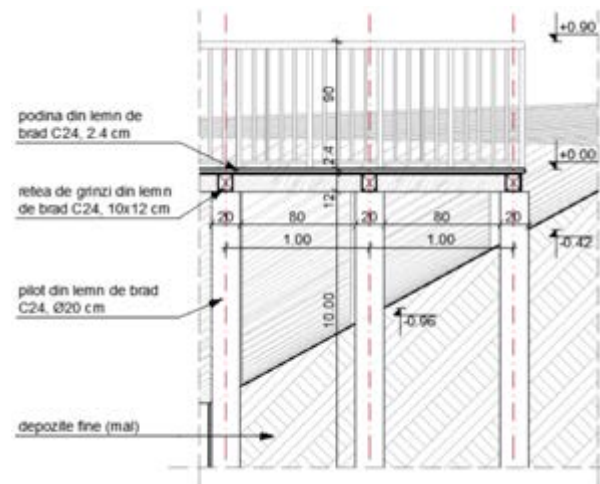


Figure 4. Section A-A.

In this study, the patented eco-friendly concrete is used to form concrete caps for extending the wooden piles in the zone of variable water level, respectively in the vulnerable area of the wood. The constituents of this type of concrete are:

- RAPIDCEM I 52,5R (PORTLAND cement unit CEM I, resistance class 52,5, R - with fast strengthening) – properties are conforming to the harmonized standard SR EN 197-1:2011 [9];
- 0/4 mm aggregate of natural river sand – aggregates are in accordance to the harmonized standard SR EN 206-1:2002 [10] and SR EN 933-1:2002 [11];
- Crushed aggregates of glass resulted from the glass crushing process in the raw glass waste form -4/8 mm, 8/16 mm –in accordance to SR EN 206-1:2002 [10] and SR EN 933-1:2002 [11];
- Silica fume (SF) – conform to the requirements of the harmonized standard SR EN 13263-1:2005 [12];
- Glass powder (GP);
- Last generation BASF superplasticizer additive, powerful water reducer - conform to the requirements of the harmonized standard SR EN 934-2:2009 [13];
- Water from the public water supply – according to the harmonized Romanian standard SR EN 1008:2003 [14].

2.2. Methods

Part 1: In the first part of this paper, the aim was to study the loads influence on the pile using the geotechnical software GEO5.

After summing all the loads that affect our pile, the following total of permanent loads is obtained, according to the equation (1):

$$Q_{total} = Q_{permanente} \gamma_{permanente} + Q_{utile} \gamma_{utile} + Q_{zapada} \gamma_{zapada} = 2.37 \cdot 10^3 \text{ daN} = 23.71 \text{ daN} \quad (1)$$

As the program evaluates the pilot's self-weight, from equation (1) the pilot has to be removed from the equation:

$$Q_{\text{peste.pilot}} = Q_{\text{total}} - g_{\text{proprie.pilot}} = 17.88 \text{ kN} \quad (2)$$

As a result, because of the small gravitational loads that correspond to each of the piles and because there are no horizontal loads considered in the analysis, there are no significant horizontal displacements of the pilots heads, excepting those from vertical loads. This effect can be seen in Figure 5 and Figure 6 as shown below.

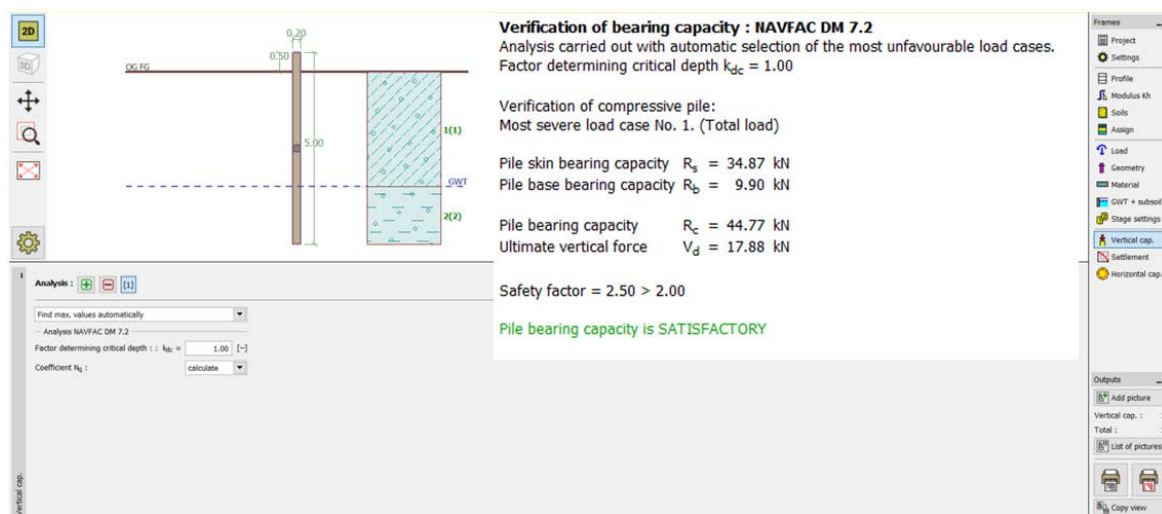


Figure 5. Verification of pile's bearing capacity.

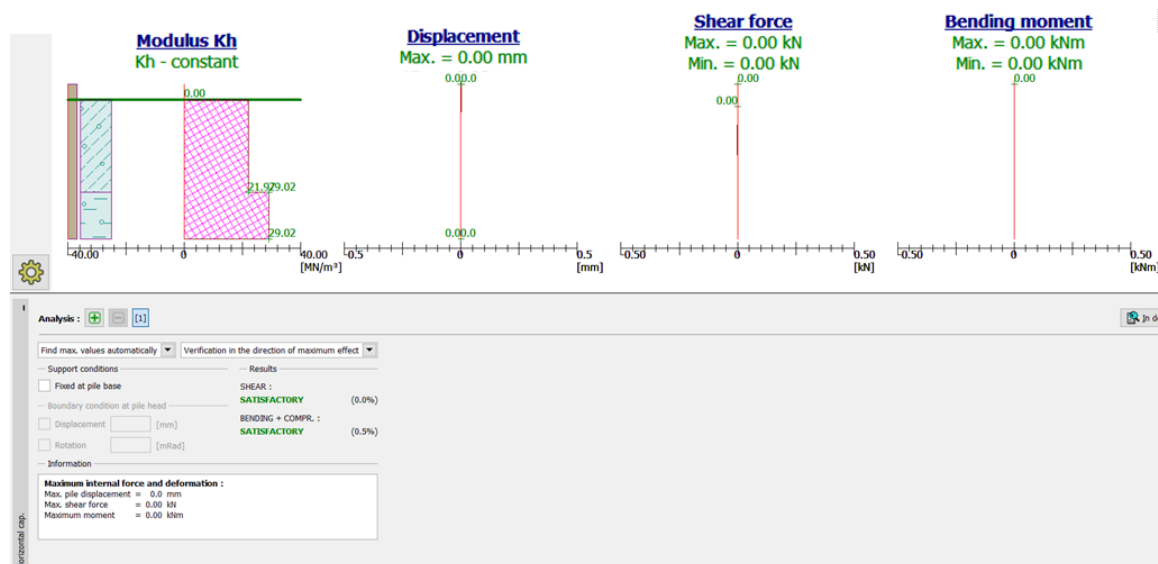


Figure 6. Verification of pile's horizontal displacement.

Part 2: The aim was to identify if concrete would suffer any visible change after his immersion for 120 days in saltwater with a very high concentration of 252.7 g/l salt (the salt deposits after the evaporation can be seen in Figure 7) from Oglinzi Baths, located in Neamț County and then to observe the result of the compression test for half cubes of eco-friendly concrete used for pilot's extension in

the structure. Thus, in the compression test, patented concrete specimens and a control mixture of concrete made of natural aggregates are used, respecting the same recipe. The test is carried out on samples that were already tested at splitting and kept under normal environmental conditions for an office.



Figure 7. Salt deposits after the evaporation of concentrated saltwater from Oglinzi Baths.

Since different mixes have been designed in order to obtain a high performance concrete with aggregates from recycled glass waste, two different samples, S8-1, A and the control mix Mr were used to perform the tests. The control mix was designed using crushed rock aggregates with 4/8 mm and 8/16 mm dimensions.

Table 1. Mixes used for experimental compression attempt.

Mix Symbol	<i>Mix Constituents</i>								W/C
	CEM Lafarge	SF Elkem	GP	Glass Agg.	River sand Agg.	Glass Coarse Agg.	Glass Coarse Agg.	Admixture Super- plasticizer BASF	
S8-1,A	0.8	0.125	0.125	0/4	45%	25%*	30%*	0.025	0.35
Mr	0.8	0.100	-	-	45%	25%	30%	0.020	0.35

*Waste glass aggregates, SF – silica fume, GP – glass powder, Admixture – additive for concrete

The resistance of glass aggregate is somewhat less than the resistance of natural river aggregates, which support the compressive strength of the concrete along with the cement. By the results obtained for the S8-1,A (using crushed glass aggregates), it is demonstrated that they can be used in concrete, with the direct use of alkali-type chemical inhibitors, which stops expansion into concrete. The inhibitors used were SF, which gives workability, increasing the density of the mixture and, implicitly, high resistance of concrete, and PS, which supports the abrasion resistance of the concrete.

Using such a type of concrete allows the development of innovative and environmentally friendly solutions that lead to a reduced consumption of non-renewable natural aggregate and minimize the environmental impact. The use of waste materials in creating new building materials or products (for example recycled glass waste) leads to a reduced of CO₂ footprint, by partially replacing cement. Recycling of glass waste and reducing the mixed cement gives the ecological/ “green” concrete status [5].

Table 2. Development of compression strength over time.

Characteristics	Mixtures	
	S8-1,A	Mr
Medium compressive strength (fcm), bending resistance (fct, fl) and splitting (fct, sp) [MPa]		
Compressive strength		
fcm 7 days	71.9	74.2
fcm 28 days	83.0	79.7
fcm 56 days	83.7	80.3
fcm 90 days	85.6	80.7
fcm 120 days	88.4	89.6
fct, sp 28 days	3.7	3.75

Table 3. Resistance classes obtained.

Mixture symbol	Medium compressive strength fcm 28	Characteristic compressive strength fck	Resistance class at initial tests fcm = fck + (6÷12) MPa (SR EN 206-1, NE 012-1:2007)
S8-1,A	83.0	75.0	C60/75
Mr	79.7	71.7	C55/67

The concrete samples were also tested at water action under 12 atmospheres pressure, according to the standard STAS 3519-76 [15] (repealed), replaced by the standard SR EN 12390-8:2009 [16]. In this situation, a very good behavior was observed allowing an insignificant penetration of water of approximately 10 mm, this value being 10 times lower than the maximum admissible evaluation of 100 mm provided in the standard SR EN 12390-8:2009 [16].

This behavior is due to the existence of silica fume (SF) in the composition of concrete S8-1,A. Using SF reduces the number of pores, increases the density of concrete and thus reduces the permeability of water in the concrete (increase the impermeability of the concrete) [17, 18].

3. Results and discussions

The main challenge of this 2nd part was to make visual evaluation for two samples of concrete (S8-1,A and Mr) and to make experimental research for them. Firstly, the concrete samples were immersed in concentrated saltwater from Oglinzi Baths for 120 days. After taking out the specimens, the S8-1,A sample had apparent deposits of salt on the glass aggregates contour, but without any visual modification. However, the Mr block had some whitish circles around the external pores, as can be seen in Figures 8 and Figure 9.

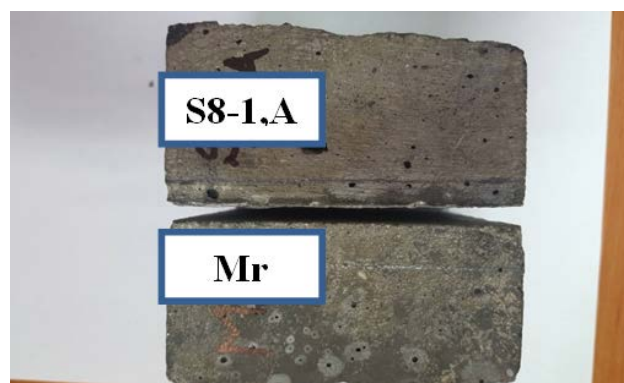
**Figure 8.** S8-1,A after immersion in saltwater.**Figure 9.** External aspect of specimens.



Figure 10. Water level penetration of S8-1,A sample.

As it was expected, because of the SF usage, the penetration in S8-1,A sample was minimum and hardly noticeable of only about 1 mm, but at the Mr specimen, there was a maximum penetration zone with about 10 mm. This value is 10 times bigger than the one registered in the case of S8-1,A. So, S8-1, A behaves much better at the action of water.



Figure 11. Water level penetration of control mix Mr.



Figure 12. Effective compression test for sample S8-1,A.



Figure 13. Effective compression test for sample Mr.

The experimental research consisted in evaluating the compressive strength of both S8-1,A sample and control mix Mr for comparing their results. Without having new mixes samples, we have used two specimens (dimension 150x150x75 mm) that were tested in 2010 at splitting and stayed, after that, for 8 years at normal temperature and humidity - in the office. So, the samples were already affected by their first test, but we have tried to displace the metal strips (dimension 150x20x9 mm) in the middle zone for the best resistance values. The compressive strength is the result of the maximal load action (F) relative to (Ac) which is the transverse action of the compression force test sample, calculated from the designated size of the specimen (SR EN 12390-1:2013[19]) or from the measurements of the sample if tested, which is exactly the size of the metal strip used on the area of specimens less affected by the previous splitting test.

Table 4. Evaluation of compressive strengths.

Mixture symbol	Compressive strength fcm 120 [MPa]	Compressive strength after experimental evaluation [MPa]
S8-1,A	88.40	86.30
Mr	89.60	86.90

Even though the specimens came from tested samples, the concrete retained its characteristics over time.

4. Conclusions

Using such a type of concrete allows the development of innovative and environmentally friendly solutions that can lead to a reduction of non-renewable natural aggregate and to a minimized value of environmental impact. By partially reducing cement from the composition and by using recycled building materials and products, the environmental impact of a new structure is reduced.

The emergence of commercial products that have waste materials from many industrial branches in composition is one of the newest and innovative aspect. Scientific community is involved and need to provide new solutions in order to build a sustainable future for humanity and for other living species.

Using mixed piles, the wood is protected by the use of concrete between the modifications of water level. To achieve the best use of materials, wood must be stopped below the minimum water level and can be continued with this type of eco-friendly concrete which creates, moreover, an impressive architectural appearance.

It can be concluded that this mixed structure can be easily be used in a real case, for a consolidation system near the concentrated saltwater lake from Oglinzi Baths, integrated into a populated environment. This type of pile within the structure is able to stabilize the soil with only eco-friendly materials and without degradation due to landslide.

In conclusion, this solution can solve the problem of wood deterioration due to alternative watering and drying periods, improving also the stability of the sites.

5. References

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