The impact of the physical state of synthetic thermoset polymer on the cementation of a radioactive resin used in softening the water of Triga Mark II reactor.

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Received 17 Dec 2015, Revised 18 Feb 2016, Accepted 07 May 2016

Abstract:
The objective of our study was designed to improve the formulation of the reference matrix by adding a load constituted by the polymer novolac oxide, while taking into account the various parameters influencing the compressive strength, particularly the time for kneading, and the physical state of the polymer in the matrix. For this we evaluated the impact of thermoset synthetic polymer on the packaging of REI at 12%. This led us to the study based on several physical states of the polymer matrix in the solid state, in granules at various percentages as well as different sizes.

Keywords: polymer novolac oxide – compressive strength – polymer matrix.

I. INTRODUCTION:
The ion exchange resins (IER) are used in the purification of water from the reactor vessel and the storage of spent fuel. REI are insoluble solids that have the powerful properties of exchanging ions contained therein with those present in solution in an equivalent manner in terms of loading.

The center of this research study is built around improving the conditioning matrix of REI as radioactive waste generated by the nuclear reactor CENM.

As part of this research, the results obtained by our collaboration has been very promoters [1, 2], which gave us the thinking of introducing the synthetic polymer as an additive in the REI conditioning matrix in order to assess the impact of the physical state of the polymer which is synthesized on the confinement matrix of REI. The methodology used for the evaluation of this approach is defined as follows:

- Determination of the percentage of REI introduced into the matrix;
- Change in percentage of water, cement and epoxy novolac polymer (PEN) added to the matrix;
- Addition of PEN in granulated form in different sizes (0.4; 0.8 mm) and different percentages (1, 2, 3, 4 and 5%).
2. Materials and methods

2.1. Basic Reagents:

Ion exchanging resin [1, 2, 3, 4, 5, 6, 7] is a cross-linked macromolecular matrix insoluble in water which can, through the contact with a solution, exchange ions therein with other ions of the same sign from the solution used in the purification of water from the TRIGA Mark II reactor vessel.

![Image 1](image1.png)

**Image 1.** Ion exchanging resins.

*Polymer epoxy novolac:* is prepared by the condensation of epichlorohydrin [6, 8, 9, 10] and a polymer polycrésol (hydroxy novolac) in alkaline medium.

![Figure 1](image2.png)

**Figure 1.** Reactional formula of the synthesis of the novolac epoxy resin [6].

*Methylene dianiline (MDA)* is known for its excellent mechanical properties and good thermal stability it provides to the final product, compared with other hardeners. Its structure is given in the figure below.

![Figure 2](image3.png)

**Figure 2.** Structural formula of methylene dianiline (MDA).

2.2. Equipment

*The used molds* are cylindrical of 5 cm in diameter and 10 cm height (Image 2).

![Image 2](image4.png)

**Image 2.** Molds.
The Mixer 3R (Image 3) is a device that ensures a uniform mixture which is of paramount importance for the quality of manufacturing processes. It provides a consistent way a mixture of homogeneity barn all by reducing the mixing time.

Image 3. The Mixer.

Press Carver 4350.L (picture No. 4) is a manual hydraulic press for determining the compressive strength of the mortar from the force measured by the surface.


3. Results and Discussions

3.1. Testing of the reference formulation:

Table 1 presents the formulation at 0% of epoxy novolac polymer:

<table>
<thead>
<tr>
<th>Constituants</th>
<th>REI</th>
<th>Cement</th>
<th>Water</th>
<th>Polymer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pourcentage (%)</td>
<td>12</td>
<td>67.92</td>
<td>20.19</td>
<td>0</td>
</tr>
<tr>
<td>Amount (g)</td>
<td>0.079</td>
<td>0.433</td>
<td>0.138</td>
<td>0</td>
</tr>
</tbody>
</table>

The results of the compressive strength for the matrices of 7, 14, 28 and 90 days are shown in Figure 3:
Figure 3. Variation of the compressive strength for the reference test according to time

- The compressive strength increases according to time for the formulation of reference up to 28 days.
- The RC max reached is $t = 28d$.
- The resistance of the reference matrix decreases from 28d and 90d.
- Picture 5 represents the status of the reference matrices containment:

![Reference test matrices](image5.jpg)

Image 5. Reference test matrices.

In the previous study [2] in which we have added the PEN as an adjuvant dissolved in the matrix and as coating on the specimen, we changed the use of the adjuvant in its new configuration at the solid granulated different dimension.

2.2. Optimization of the percentage of the solid state and particle size of the PEN

In this study, we tried to introduce the novolac solid epoxy polymer in the cement matrix to improve the compressive strength. The used solid polymer is introduced into the matrix in different percentages (1, 2, 3, 4 and 5%) and of granulometric sizes (0.4 and 0.8mm).
2.2.1. Polymer Introduction of 1% in two sizes 0.4 and 0.8 mm

In this study, we investigated two cases of polymer at the level of sizes (0.4 and 0.8 mm). Picture 6 shows the size of the solid polymer according to two sizes:

![Image 6. Solid Polymer of 0.4 mm and 0.8 mm sizes.]

The results of the compressive strength for the matrices of 7, 14, 90 28 and 90 days are shown in the following table:

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>Resistance to 1% of solid polymer at 0.4 mm (MPa)</th>
<th>Resistance to 1% of solid polymer at 0.8 mm (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>11.82</td>
<td>6.86</td>
</tr>
<tr>
<td>14</td>
<td>13.32</td>
<td>9.94</td>
</tr>
<tr>
<td>28</td>
<td>17.35</td>
<td>13.12</td>
</tr>
<tr>
<td>90</td>
<td>8.15</td>
<td>7.97</td>
</tr>
</tbody>
</table>

Picture 7 shows the state of confinement matrices:

![Image 7. Matrices test of 1% polymer at 0.4 mm and 0.8 mm.]

The results of tables 2 are illustrated in Figure 4.
Figure 4. Variation of the resistance to compression for the matrices of 0.4mm and 0.8mm according to time.

- The compressive strength increases according to time for the formulations of 1% in two sizes 0.4 and 0.8 mm of polymer novolac epoxide.
- The compressive strength increases according to time for the reference matrix.
- The compressive strength of the dies with the epoxy novolac polymer of this test is greater than the reference matrices.
- The strength of the matrix polymer of 0.4 mm is greater than that of 0.8 mm matrices.

On the basis of these results, we concluded that these test results showed an influence on the matrix of cement, REI and water, the matrices of granulometry of type 0.4 mm have more influence on the compressive strength compared to 0.8 mm. This particle size of 0.4 mm has been set for the remaining percentages.

2.2.2. The introduction of the polymer (PEN) of 1, 2, 3, 4 and 5% at 0.4 mm:

The results of the compressive strength for the matrices of 7, 14, 28 and 90 days are shown in Table 3, which is reflected by Figure 5.

Table 3. Resistance of the matrices of 1, 2, 3, 4 and 5% (0.4 mm).

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>Resistance 0% of polymer (MPa)</th>
<th>Resistance 1% of polymer (MPa)</th>
<th>Resistance 2% of polymer (MPa)</th>
<th>Resistance 3% of polymer (MPa)</th>
<th>Resistance 4% of polymer (MPa)</th>
<th>Resistance 5% of polymer (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>8.06</td>
<td>11.82</td>
<td>8.06</td>
<td>12.56</td>
<td>12.24</td>
<td>7.02</td>
</tr>
<tr>
<td>14</td>
<td>8.43</td>
<td>13.32</td>
<td>11.53</td>
<td>12.93</td>
<td>12.84</td>
<td>11.78</td>
</tr>
<tr>
<td>28</td>
<td>11.06</td>
<td>17.35</td>
<td>14.41</td>
<td>13.125</td>
<td>13.03</td>
<td>12.88</td>
</tr>
<tr>
<td>90</td>
<td>10.87</td>
<td>8.15</td>
<td>11.29</td>
<td>12.93</td>
<td>13.31</td>
<td>10.90</td>
</tr>
</tbody>
</table>
Figure 5. The variation of the compressive strength for the matrices according to time

- The compressive strength increases according to time for the formulations of 1% to 5% of epoxy novolac polymer, and for the reference matrix.
- The compressive strength of the matrices with the epoxy novolac polymer of this test is greater than the reference matrices.

From these results, we concluded that the introduction of the polymer of 1, 2, 3, 4 and 5% in the matrix increases the compressive strength compared to the core matrix and that the matrix of 1% of polymer has a compressive strength greater than the others.


The study of the dispersion of the charge formulation is displayed from dispersion of the reinforcement and the waste (REI) in the binding matrix.

Our formulations were analyzed by scanning electron microscopy, and the obtained results were visualized by SEM pictures.
According to observations by the SEM, these formulations developed by granulated novolac (Ps) / REI / water / cement showed us the appearance of spherical fillers of REI on the analyzed surface according to Figure 6.

4. Conclusion
In this context, several research studies have been conducted [1,2] to determine the formulation which has a better resistance to the compressibility compared with the basic formulation conditioning of the REI. The adopted methodology to evaluate the impact of epoxy novolac polymer (PEN) of different physical states (granules) in the ion exchange resins containment matrix is done by fixing the percentage of REI and the changing percentage of water, of cement and epoxy novolac polymer.

The obtained results in this study showed an increase in the compressive strength (RC) after containment time of 7, 14, 28 and 90 days compared to the basic formulation.

The introduction of the epoxy novolac polymer (PEN) as granulated form in different percentages (1, 2, 3, 4 and 5%) and different sizes (0.4 and 0.8 mm) have shown a positive impact on the matrix, which results in an improvement of the compressive strength (RC) of the matrix of 1% epoxy novolac polymer with a particle size of 0.4 mm on the one hand, and a good dispersion of polymer in the second matrix.

Acknowledgements-This work has been supported in part by the National Center of Scientific and Technical Research (CNRST).

References


