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The optimization of experimental parameters of the synthetic polymer containment in the conditioning of solid radioactive wastes used in the purification of the circuits of TIGA Mark II reactor

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Abstract: In this study, we treated the conditioning of radioactive wastes by the method of management [1] using the ion exchange resin (IER) as radioactive waste [1-3]. From the values obtained by experimental studies [2], we were able to optimize the conditioning process by the experiments plan approach using the NEMRODW software. The objective of this article is an in-depth theoretical study of the conditioning of radioactive wastes with the introduction of an adjuvant which is the synthesized polymer. The optimization of parameters by this software has enabled us to determine the optimal conditions for a better packaging. The influenced theoretical parameters results in the most adopted parameter to optimize the number of experiences used for the conditioning of ion exchange resins to obtain a better formulation to reduce the number of the realized tests on the one hand, and to increase the resistance to the compression of matrices in polymer on the other

Keyword: Conditioning, ion exchange resin, experiments plan, resistance to the compression.

1. Introduction

At the present time many manufacturing processes, materials or laboratory experiments are becoming increasingly complex because they depend on a large number of variables which are difficult to adjust intuitively. Only the realization of experiences will help to understand and to model such complex phenomena. If these experiments are performed without a rigorous methodology, it is likely that they will lead to dead ends (model not to adjust, inconsistent results, etc ...) or the results of disappointing quality. This is why the method of experiments is recommended to optimize this type of approach [4]. The main objective of this method can be summarized by the motto: Get maximum information in a minimum of experience, and seeking simultaneous changes for all controlled variables. This issue is crucial in industry where minimizing the number of experiments to be performed is synonymous with time-saving and productivity [5, 6]. And it also enables

researchers to analyze real phenomena and predict the results from the application of one or more theories at some level of approximation; this is why, we intended to adopt the NemrodW modeling software [4 -7].

To this end, we have implemented a plan of experiments to study the influence of variations of four components in the conditioning of the sample consisted by (Cement, REI, Water and polymer [2]) and its influence on the resistance to compression [8].

2. Materials and Methods

2.1. Description of the study

We studied the effects of four factors: Cement (U1), the Ion-exchange resin (REI) (U2), Water (U3) and polymer (Epoxy Resin Novolac [9]) (U4) on the response (Compressive strength).

2.2. Reply

The measured response Y is the compressive strength of mortar for a period of 28 days.

Y = the value of the compressive strength

2.3. The Working Principle

We have carried out tests in advance so as to determine, with a minimum of trials and with maximum precision, the influence of multiple parameters of the mortar composition on the measured values of the response Y (compressive strength).

3. Results and discussion

The software helps to conceptualize and analyze the experimental strategies. This software, which is exclusively dedicated to the plans of experiments, tends to reduce the number of operations at the level of the determination of process control parameters. It can also make use of their results statistically and reliably.

3.1. Experimental area of interest

This table 1 shows the minimum and maximum values of the various factors considered:

Table 1. Experimental Area of Interest

	Factor	**No. Levels**	**Levels**
U1	Cement	2	0.435 Kg 2.039 Kg
U2	REI	2	0.017 Kg 0.365 Kg
U3	Water	2	0.021 Kg 0.721 Kg
U4	Polymer	2	0.004 Kg 0.060 Kg

3.2. Test results

The variation of the compressive strength (Y) in view of test mode are shown in figure 1.

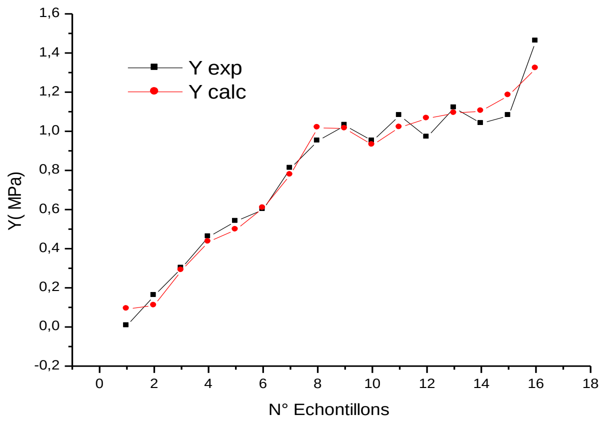

Figure 1. graph of the experimental and calculated compressive strength

3.3. Mathematical modeling

The responses are described by a model as follows:

Y = b0 + b1 * X1 + B2 * X2 + b3 * X3 + b4 * X4 + b12 * (X1 * X2) + b13 * (X1 * X3) + b23 * (X2 * X3) + b14 * (X1 * X4) * b24 + (X2 * X4) + b34 * (X3 * X4)

3.4. Graphics of weights

The influence of factors and their interactions are evaluated through the model coefficients. The Pareto diagram represents an aid to interpretation. For this purpose, the compressive strength results are shown in the diagram (Figure 2), which shows that the most important effect on the complexation are those of water (b3), the polymer (b4) and the interaction between them (b34) is remarkable.

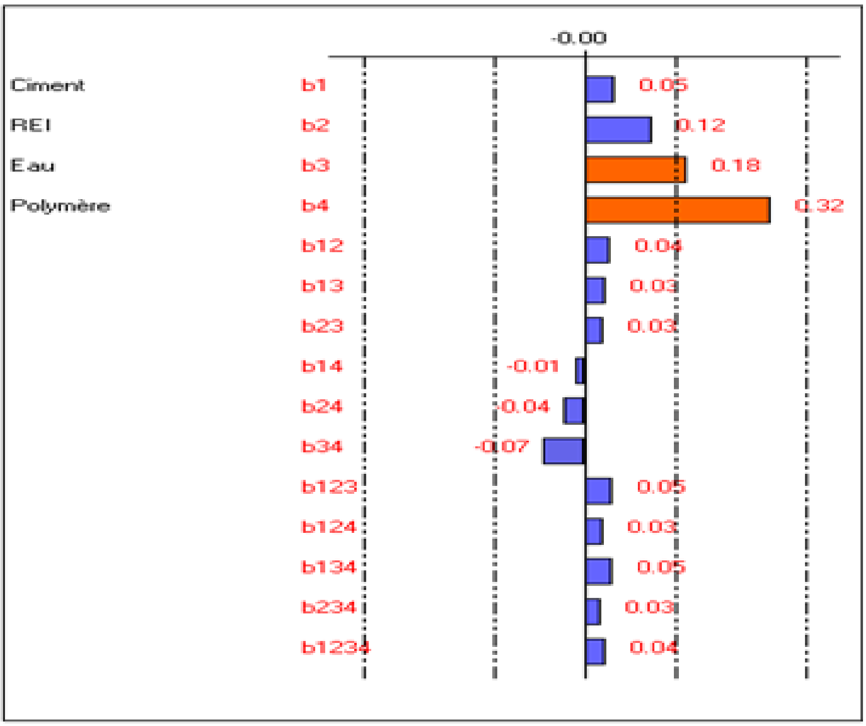

Figure 2. Average effects of parameters on compressive strength.

3.5. Graphic study of the effects of the response Y

3.5.1. Methods of HENRY's Right

This method of tends to represent the effects of the distribution function (or bj | bj |) on Gausso-paper arithmetic. We obtain two graphs. The Normal Plot graph with bj and the Half Normal Plot graph with | bj | (Fig. 3),

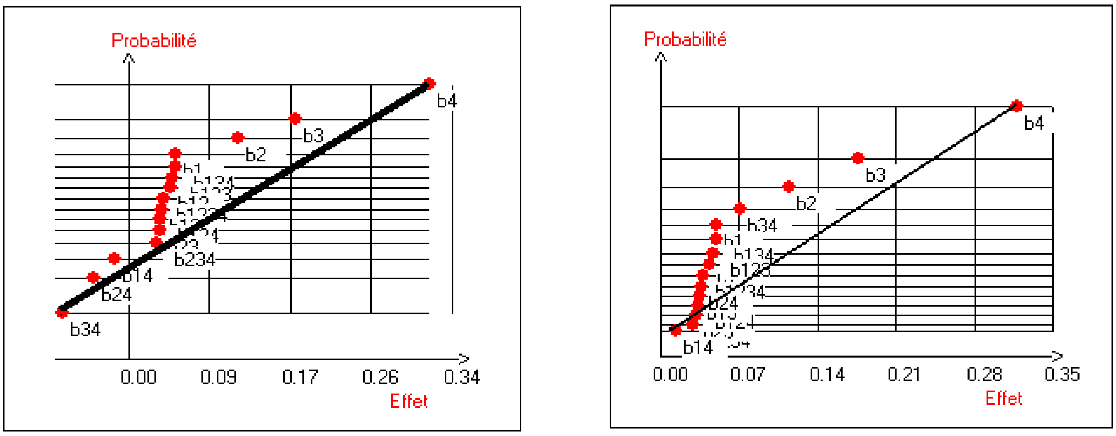

Figure 3: HENRY's Right

The effects that deviate from the Right on the plot below the top of the right (according to the fact that the effects are positive or negative) are considered as "probably active"

The graph of the Half Normal Plot shows more clearly the active coefficients but it gives no sense here since we consider the absolute value of coefficients.

The coefficients b4 and b3 (effects of cement and water respectively) are probably active, which comes into agreement with the results obtained in the Patero diagram. This causes the coefficients b34 interactions (interaction water / polymer) which are likely active.

3.5.2. Graphic Study of interactions

The study of the effects of factors was necessary to know the main effects of the factors and the interaction effects between factors. An interaction is a combination of factors which are not acting independently.

Graphic Study of the interaction Cement / REI

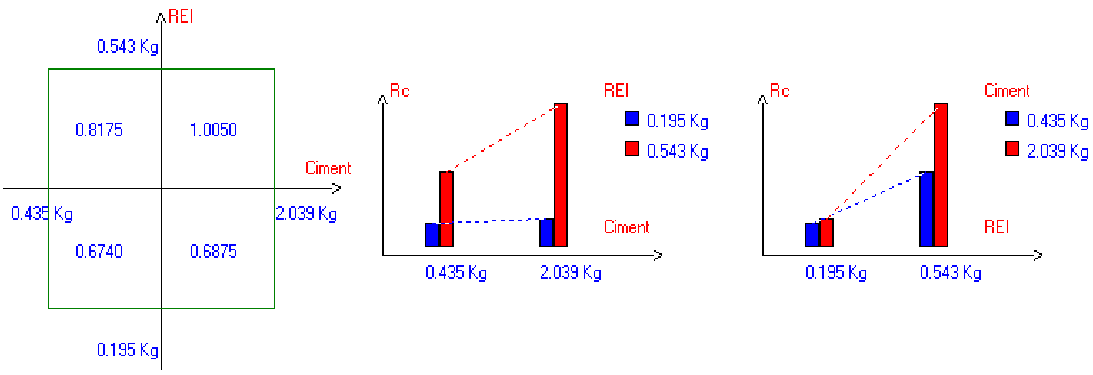

Figure 4: Graphic Study of the interaction Cement / REI

Through this study, we noticed that there is no interaction between cement and water. This is due to the fact that each component has an effect on resistance to compression regardless of the other (Fig. 4).

Graphic Study of the interaction Cement / Water

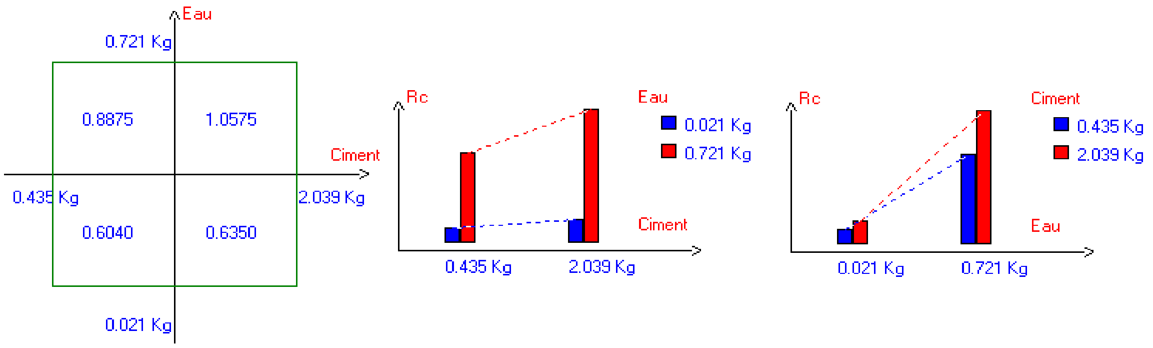

Figure 5: Graphic Study of the interaction Cement / Water

The same applies to the amount of water and cement, it clearly appears to us in Figure 5 that there is no interaction between these two components. Therefore each of them had its own effect on the compression strength without using the other.

Graphic study of the interaction Cement / Polymer

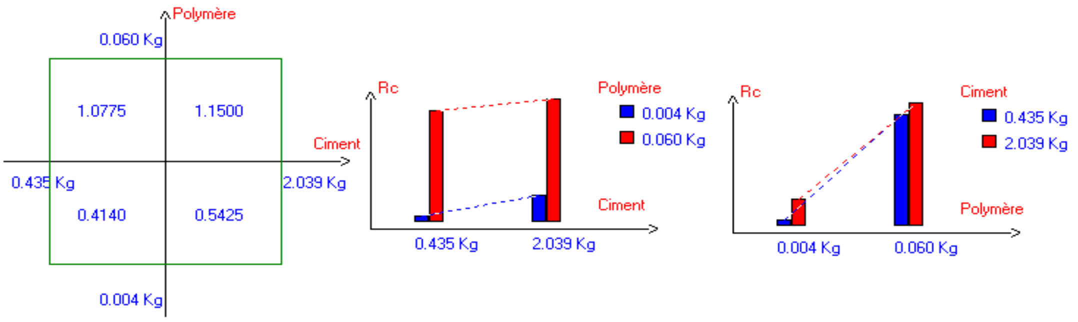

Figure 6: Graphic Study of the interaction Cement / Polymer

We noted in Figure 6, according to the graphical representations of the interaction effects, that the amount of cement and polymer has an influence on the compressive strength.

Graphic study of the interaction water / REI

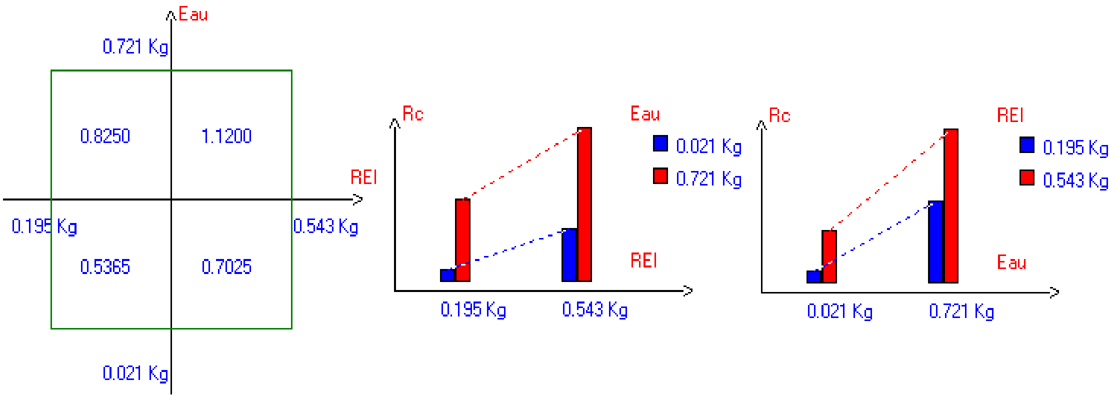

Figure 7: Graphic Study the interaction water / REI

The same applies to the amount of water and IPE since it appears to us, according to Figure 7, that there is no interaction between the two components. So each of them has its own effect on the compressive strength without using the other.

Graphic study of the interaction polymer / REI

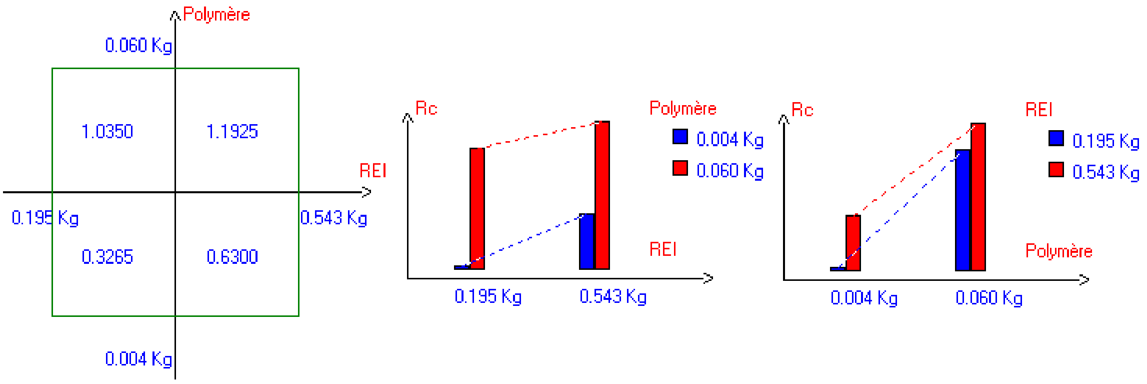

Figure 8: Graphic Study the interaction Polymer / REI

According to Figure 8 which reflects the interaction between the amount of water and the cement, it appears to us that there is no interaction between these two components. Therefore each of them has its own effect on the compression strength without using the other.

Graphic study of the interaction water / polymer

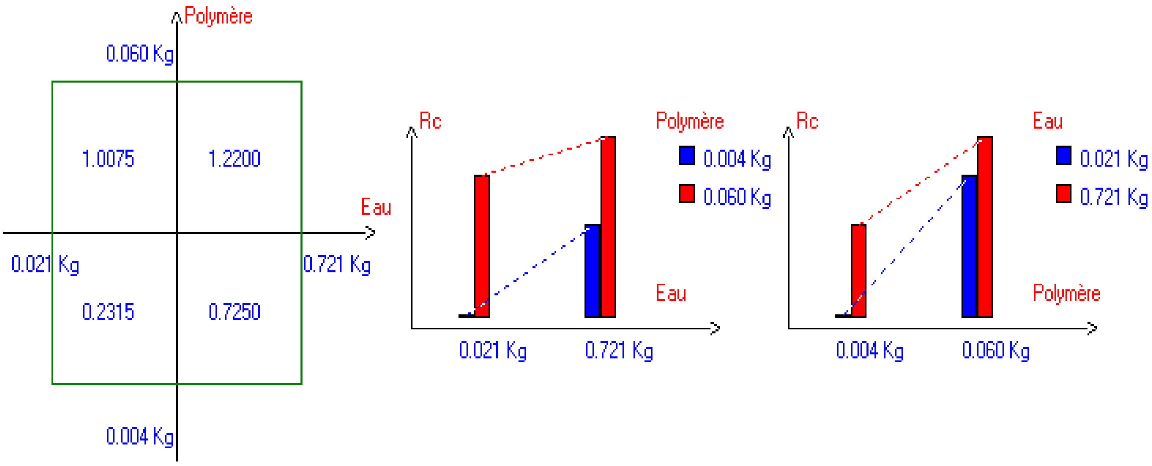

Figure 9: Graphic Study the interaction Polymer / Water

Similarly to the amount of water and the polymer, it appears clearly to us that there is no interaction between the two components. Each of them has its own effect on the compressive strength without using the other (Figure 9).

3.6. Validation of the plan: the compressive strength Y

3.6.1. Validation of the model

The treatment of various parameters by the diagrams (bar graphic and Pareto graphic) allowed us to highlight that the regression coefficient is around 91.9% (Table 2) based on the analysis of variance represented as follows:

Table 2. Variance analysis

Source of variant	Sum of squares	Degrees of freedom	Average square	Report	Signif
Regression	480.2314	6	860.4567	1.6204	91.9%
Residues	401.5002	1	40.3275	**	
Total	530.6534	7	**		

For the optimized formulation, the tests were carried out in the laboratory on concrete cylindrical specimens of 10x10x5 diameter;

As part of this work, the various tests carried out allowed to propose a new formulation of the cement matrix with other physical state of polymer:

This work allowed us to optimize the performance of the conditioning process, reducing the number of product while keeping the compressive strength of the mortar, reducing the time of conditioning the resin and reducing the number to store in the storage building.

4. Conclusion

We noticed the importance of the introduction of polymer in the formulation of the conditioning of radioactive wastes using the software Nimrod W. The efficiency of the compressive strength depends on several factors, mainly those of cement, ion exchange resins (IER), water and polymer. The most influential effect on the water resistance are (b3), the polymer (b4) and the interaction between them.

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