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Influence of the penetrability of the new bitumen and the temperature of manufacture on the resistance of the asphalt recycled to the fatigue

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Abstract

Climatic and traffic effects are the causes of aging of the surface layer of asphalt, which leads to the necessary renovation of the latter. The use of waste from the tread layer provides a viable and beneficial solution for the environment and the economy. However, this solution must meet the requirement of sustainable development, which necessitates that a road has a very long lifespan. In this study we investigated the performance of recycled asphalt in terms of fatigue (as an element of life-cycle control). All the formulas were tested by the fatigue test in order to define the influence of the proportions of the asphalt aggregates, penetrability of the new binder used, and the manufacturing temperature. The results obtained showed the relationship between the contribution binder (reproduced between the new binder and the old binder) and the fatigue resistance under the influence of the parameters that we have mentioned above. At the end an optimization study has been carried in order to determine exactly the doses required to formulate recycled asphalt resisted to fatigue, the optimization seeks to maximize the asphalt aggregates and minimized the temperature of manufacture with a class of the binder compatible.

Key words: Asphalt, fatigue, Binder, Environment, Penetrability

1 Introduction

The pavement roads age under the action of traffic and climate aggressions, what leads at the end of their life, in layers over the characteristics compatible with the functions required by the regulations or the needs envisaged by the employer [1]. In Algeria, the asphalt aggregates for the maintenance of the rolling asphalt layer are rejected into nature or reused as a layer of Foundation for low-traffic roads [2]. But after the Rio Summit in 1992, environmental awareness has emerged that sustainable development is the link between economic growth and environmental protection [3]. On applying the concept of sustainable development in the field of road construction, the latter which requires minimizing the use of non-renewable natural raw material and the construction of a road that has a very long age [4]. The logical answer to this problem is recycling that imposes the valorization of the deposit of materials existing in the pavement and limits the amount of new materials in the formulation of the new asphalt [5]. In this study we checked the effect of the penetrability of the contribution Binder, asphalt aggregate dosing and the temperature of manufacturing on the resistance to fatigue of asphalt recycled. The formulated type asphalt is BBSG 0/14 (Semi-dense bituminous concrete), because this is the type most met in Algerian road. The hypothesis in this work is that asphalt aggregates have a percentage of old binder which can cause fatigue for recycled asphalt, but very precise control of contribution Binder (old binder + new binder) of asphalt recycled can tell us the new binder corresponding with the percentage of asphalt aggregates used, also temperature of manufacturing so that the mixture (old binder and new binder) may take the form of a contribution binder compatible with the feature asphalt recycled manufactured. The asphalts are subject to solicitations of short durations and repeated in time. They correspond to the successive passages of the axles of vehicles [6]. Traction by bending phenomenon occurs at the base of different layers of the floor [6]. The induced stresses do not result in an immediate termination, but their repetition in time is at the origin of a cracking by fatigue [7]. A program of fatigue tests was carried out to determine the resistance to fatigue of asphalt recycled formulated with binders of various penetrability, asphalt aggregates took three percentages (15%, 45% and 75%) and temperature of manufacturing has changed degree. The fatigue test that we have done is made on samples of trapezoidal shape that is being tested in bending two points [8]. Under review is the maximum deformation experienced by the extreme fibre of the test piece during a sinusoidal amplitude constant arrow solicitation. This deformation is calculated from the arrow head assuming linear and homogeneous material [9]. The fatigue in the laboratory test to determine the deformation $\varepsilon 6$ leading to the rupture of a specimen by fatigue under certain test conditions [10]. An optimization study has been carried in order to determine exactly the doses required to formulate recycled asphalt resisted to fatigue, the optimization seeks to maximize the asphalt aggregates and minimized the temperature of manufacture with a class of the binder compatible. For this logic the rate of asphalt aggregates, the binder (penetrability) and the temperature of manufacture were modified for different mixtures. The purpose of this method is to reduce the number of experimental tests required for a study and have the maximum of information. The hypothesis of formulation used here seeks has increased the rate of asphalt aggregates to maximum and minimized the temperature of manufacture. Also the assumption implies a total remobilization of the old binder in asphalt aggregates and seeks a binding nine compatible with the mixture. What has led us to follow the evolution of the penetrability and softening temperature for each test, it allows for more, controlled the influence of these parameters on the mechanical performance of recycled asphalt. The plan of experiments used is a complete response surface design (ANOVA). It was used to characterize the evolution of a magnitude depending on 3 parameters. For this, the experimental points which will have to be characterized are part fixed by the plan of experiences. The experimenter chose the parameters to be considered, as well as the range of value on which each parameter is changing: a minimum value and a maximum value. The theory of the experiences plans requires that the mid-point of this range is a point to characterize. The three points median each parameter defines the center of the experimental field of study. The model a priori is entered under the form YJ=f(XI) or the function f is a polynomial of order more or less high of xi.

2 Parameters of the study

Three parameters were controlled in this study in order to determine their influence on the resistance to fatigue of the asphalt recycled.

2.1 Percentage of asphalt aggregate

Asphalt aggregate percentage is chosen to cover a range from the case of recycling at low rates (15%), achievable common with most existing asphalt central, until the case of recycling at high rate (75%) corresponding to the maximum capacity of recycling in the asphalt central with double drums dedicated to the production of asphalt recycled at high rate. The choice of these two values, maximum and minimum, requires an intermediate point to 45% of Asphalt aggregate corresponding to the rate of recycling in the asphalt central with deported burner.

1.1. Manufacturing temperature

The minimum temperature of manufacturing is chosen equal to 120 ° C; this is the temperature to which the old binders start to be remobilized. Used maximum temperature is fixed at 160 ° C, or above this temperature, it is in contradiction with the concept of sustainable development that requires a minimum consumption of non-renewable energy. The choice of these two values, maximum and minimum, requires an intermediate point to 140 ° C close to temperature of manufacturing of standard asphalt.

1.2. Binder penetrability

The penetrability is the measure of the pressing of a needle normalized in a binder maintained at a fixed temperature, after 5 seconds under a load of 100 g [11]. In this study we used three binders have got different penetrability (42 m.m, 65 m.m and 90 m.m) to determine the influence of the latter with the old binder of the asphalt aggregates on the production of a contribution binder compatible with the recycled asphalt that we want to make it.

3 Materials used

3.1 Choices of new aggregates

New Aggregates choice must be done carefully because its characteristics play a very important role in the quality of the asphalt [12]. Used aggregates in this study are the fractions 0/3, 3/8 and 8/14. The (figure 1) presents the results of the Particle size analysis test.

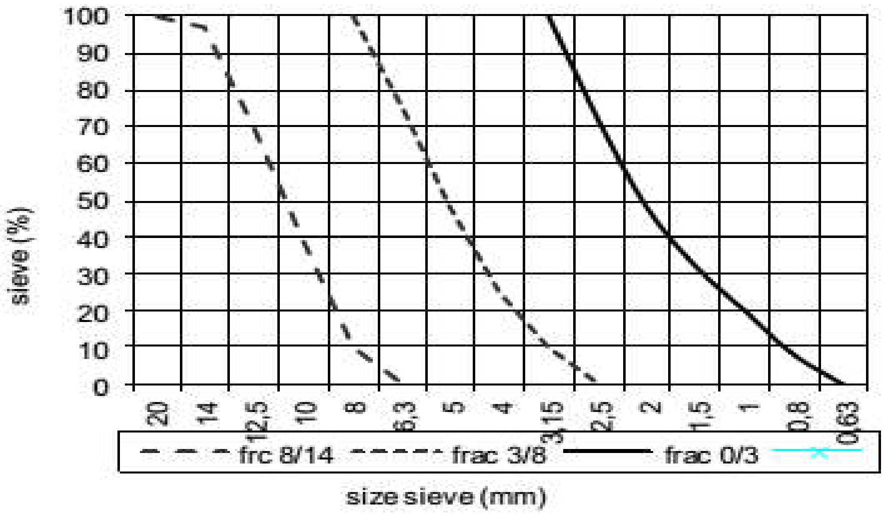

Figure 1: Particle size analysis of fractions 8/14, 3/8 and 0/3

3.2 New binders

The characterization of the bituminous binder mainly reflects the consistency at ambient temperature. This information enables to classify the bituminous binders in rank. Binders used in our study are 30-50, 50-65 and 65-100 classes. There characteristics are presented to the table 1.

Table 1: New Binders Characterization.

Sample	**Penetrability at 25°C, (1/l0 mm)**	**penetrability at 25°C, (1/l0 mm)**	**moyen**	**Specifications**
Sam 01	43	40	41.5	35-50
Sam 02	64	64	64	50-65
Sam 03	92	88	90	65-100

3.3 Asphalt Aggregate

In this study asphalts aggregates used have an age of five years of utilization as layer of bearing. They are shown that recycled asphalt can reach 100% of asphalt aggregate if it is well calibrated [13]. For this reason that the asphalts aggregates used were spent in the sieve 14 mm to eliminate the upper elements to14 mm. After the selection of the elements less than 14 mm a particle size analysis was conducted as show on the figure 2.

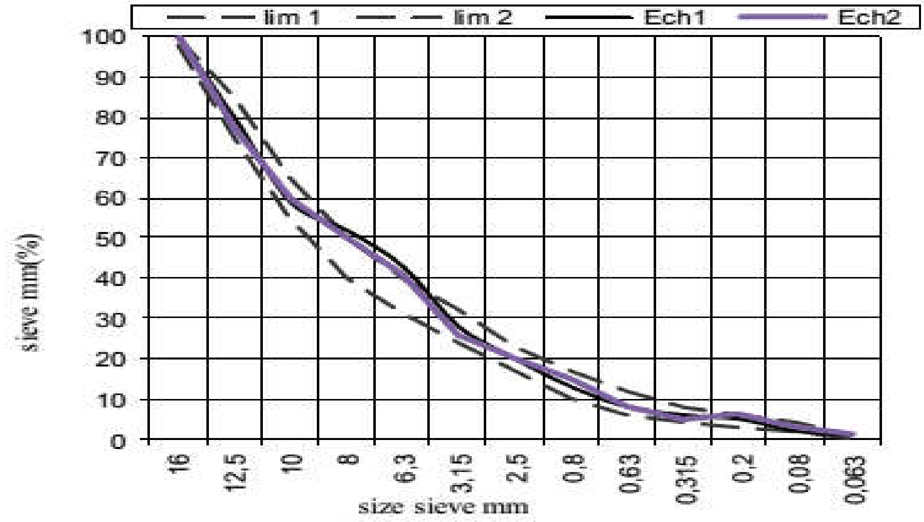

Figure 2: Particle size analysis of asphalt aggregate

4 Testing campaign

4.1 Formulation of Healthy asphalt

The Healthy asphalt made is a BBSG (Semi-dense bituminous concrete). The choice of formula through the determination of a mixture having the best ability to compaction and which could give greater stability to the hydrocarbon mixture. Marshal test results in the table.2 confirmed the percentages of fractions as well as the rate of the binder. The binder used in this formulation is 35-50 class, because this binder is recommended for the BBSG.
This formula of healthy asphalt has been the subject of control by the fatigue test in order to determine its resistance to deformation. The results of the stress test showed that after 15000 cycles the healthy asphalt deforms fast and it begins to take the plastic State. Therefore acceptable ultimate deformation equals 100 ε6 as represented on the figure 3. This ultimate deformation will be considered a limitation agreed for the recycled asphalts to they are going to be studied.

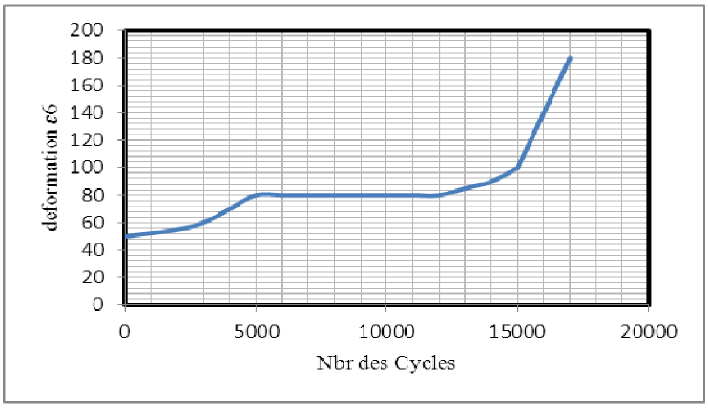

Figure 3: Fatigue test result on reference healthy asphalt

Table 2: Results of the Formulation of Healthy asphalt

Frac 8/14	45%	**Norme**
Frac 3/8	30%	
Frac 0/3	25%	
TL	5.4 %	≈5.4%
Fluage marshal	2.60	F<4
Compactness = C	96%	95%< C

4.2 Fatigue tests for asphalt recycled

The table 3 contains formulations that have been programmed in this campaign tests, a control of fatigue as well as the penetrability of the contributions binder have been made for all mixtures of recycled asphalt. Asphalt aggregates dosing Protocol is based on the results of a particle size analysis of each fraction in the healthy mix asphalt, or must cancel the amount of healthy aggregate in each fraction and replace it with the asphalt aggregates. Fatigue test is to apply for the test specimen at a fixed temperature (10 ° C) and a fixed frequency (10 Hz). The fatigue test is also done in mode of deformation. A large number of cycles are applied up to the rupture of the test piece. To test the behavior to fatigue of a mix, at least 4 test tubes must be tested at different levels of deformation [14].

Table 3: Formulations programmed in this campaign tests

N° test	AE %	T°	Class of bitume		N° test	AE %	T°	Class of bitume
01	15	120	35-45		**15**	75	140	50-65
02	45	120	35-45		**16**	15	140	65-100
03	75	120	35-45		**17**	45	140	65-100
04	15	120	50-65		**18**	75	140	65-100
05	45	120	50-65		**19**	15	160	35-45
06	75	120	50-65		**20**	45	160	35-45
07	15	120	65-100		**21**	75	160	35-45
08	45	120	65-100		**22**	15	160	50-65
09	75	120	65-100		**23**	45	160	50-65
10	15	140	35-45		**24**	75	160	50-65
11	45	140	35-45		**25**	15	160	65-100
12	75	140	35-45		**26**	45	160	65-100
13	15	140	50-65		**27**	75	160	65-100
14	45	140	50-65					

5 Result and Discussion

From the results of this study, we can distinguish clearly the influence of the rate of aggregate asphalt, the temperature of the manufacturing and class of contribution binder (penetrability) on the resistance of asphalt recycled at the fatigue. For mixtures made with new binder class (35-50) and a temperature of manufacturing equal T ° = 120 °, resistance to fatigue, represented on the (figure 4), is low for mixes when asphalt aggregate rates of exceeds 25%, reflecting that the temperature was unable to transform the old binder to the presence of the new binder a contribution binder that has the characteristics required by regulation. The (figure 5) represents the results mixtures formulated in new binding class (50-65), when fatigue resistance is acceptable up to a rate of less than 50% of asphalt aggregate in temperature of the manufacturing equal 120°, this explains the class of the binding agent used to play a role in the cohesion of the components of the mixture and the increase in its resistance to fatigue. However for mixtures when used with new binder is class (65-100) and temperature of the manufacturing 120° as shown on the (figure 6), fatigue resistance is totally weak because of the contribution binder which is not compatible with the recycled asphalt manufactured BBSG and resistance to the fatigue desired because with a contribution Binder of high penetrability cohesion becomes weak. Mixtures made in a temperature of manufacturing equal T ° = 140 ° or T ° = 160 ° gave the results have deferential behavior with mixtures produced in a temperature T ° = 120 °. For an recycled asphalt manufacturing with binder class bitumen (35-50), fatigue resistance is undesirable when the asphalt aggregates rate exceeds 50%, see the figure 6, this explains the rate of the old binder that influence the new binder to produce a contribution binder of very low penetrability and asphalt it becomes very stiff which causes a fast break. For mixtures made with a binder of class (50-65) the results gave acceptable resistance to fatigue for all formulas because the contribution binder reproduced by new binder and old Binder has got a penetrability compatible with the recycled asphalt formulated (BBSG), presented in the figure5. However for mixtures made with binder class (65-100), fatigue resistance becomes acceptable to mix them the rate of asphalt aggregate over 50%, this translated for a low rate asphalt aggregate contribution binder reproduced has very high penetrability, which causes a high flexibility and asphalt recycled it becomes fragile, but with a high rate of asphalt aggregates the old binder without the penetrability of the new binder to produce a contribution binder of desirable penetrability for the manufacturing of recycled asphalt BBSG type in the figure 5.

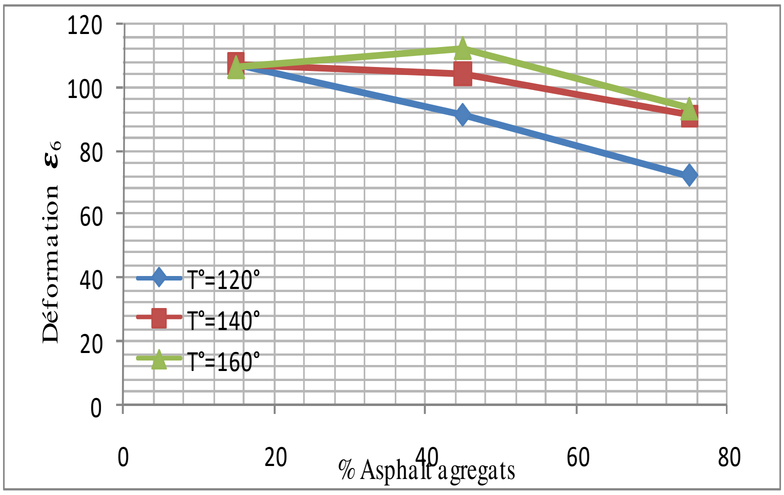

Figure 4: The fatigue of asphalt aggregates with new binder of penetrability 42 m.m

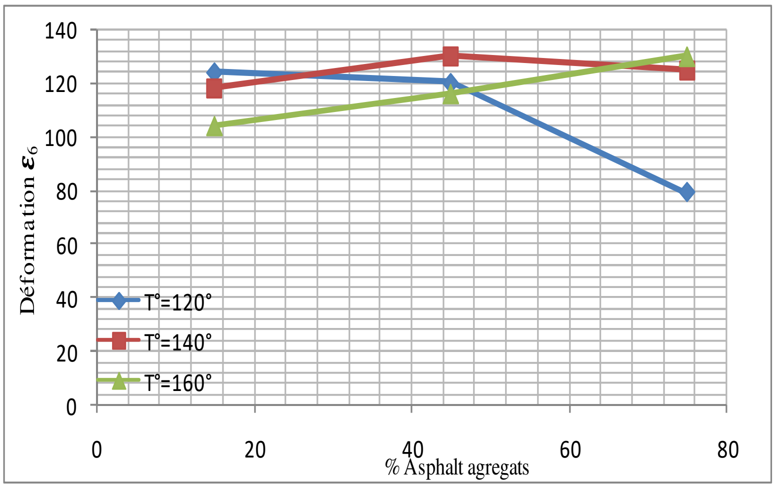

Figure 5: The fatigue of asphalt aggregates with new binder of penetrability 65 m.m

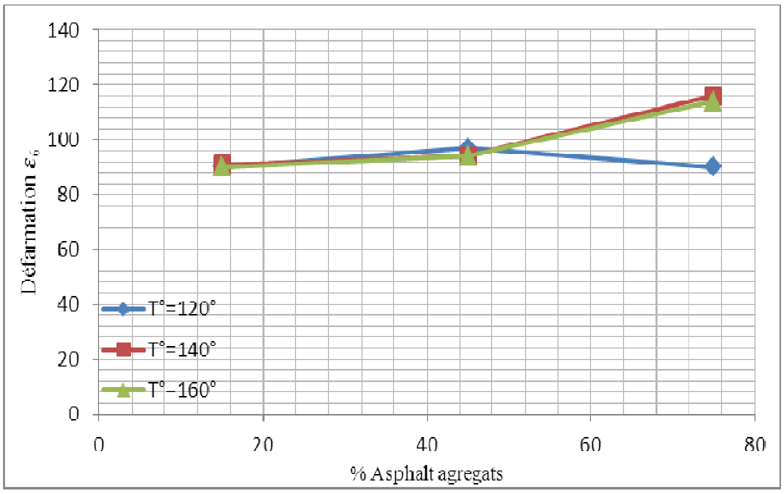

Figure 6: The fatigue of asphalt aggregates with new binder of penetrability 90 m.m

6 Optimization of a formulation of recycled asphalt resistant to the rutting

Following the results presented above, the tests performed by the classic method do not have the capacity to provide accurate results on the rate of AE and the degree of the manufacturing temperature and the class of the binder in the mixture as a function of the mechanical quality desired (fatigue), which has guided the study to the method of the plans of experience (ANOVA). In this experimental plan three factors have been proposed, the answer find is the behavior of the recycled asphalt to fatigue and the influence of factors study on the response for each formula also the compatibility of binders with the performance wish. After operating the factorial experiment that we have chosen as a model of quality, the use of software Minitab.17 We helped to program the necessary testing and the resolution of equations polynomial. The results obtained are the determination of the unknowns of the polynomial presented above in the equation (1) which expresses the resistance of recycled asphalt to fatigue (response) in function of the parameters of the experience plan (factors) .This equation will allow us to determine the resistance to fatigue in function of these variables (factors). Also this equation is a prior justification for the manufacturers of asphalt in the central of production of asphalt.

$$Fat = -453{,}9 - 3{,}021\ AE + 6{,}049\ T° + 6{,}584\ Pen - 0{,}00884\ AE^2 - 0{,}02052\ T°^2 - 0{,}03595\ Pen^2 + 0{,}02167\ AE*T° + 0{,}01250\ AE*Pen - 0{,}01719\ T°*Pen \quad (1)$$

According to the results presented on the graph of PARITO in the figure.7, one finds that the interaction between the aggregates of asphalt and the penetrability of the binder plays a crucial role. The interaction between the three factors and the interaction between the temperature of the manufacturing process as well as the penetrability of the binder have shown their influence on the quality of recycled asphalt. These results have confirmed the classic tests performed or we have seen that the rate of aggregate of asphalt contains a percentage of the old binder which affects the mechanical performance of recycled asphalt also the temperature it has a direct relationship with the remobilization of old binder for the put him compatible with the mixture.

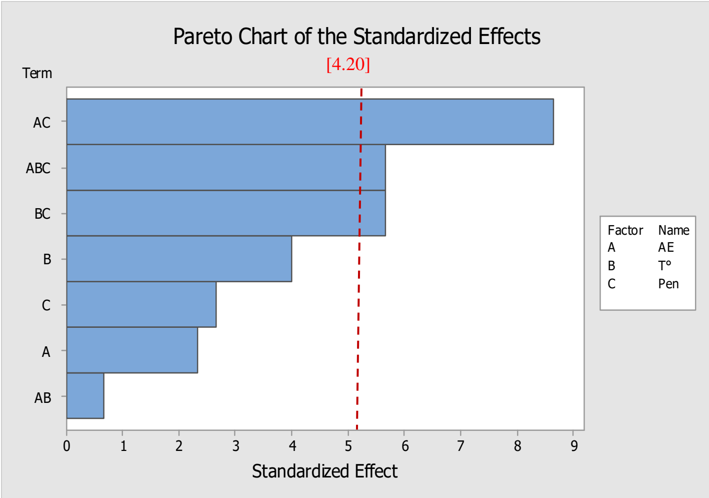

Figure 7: The Pareto chart of the standardized effects

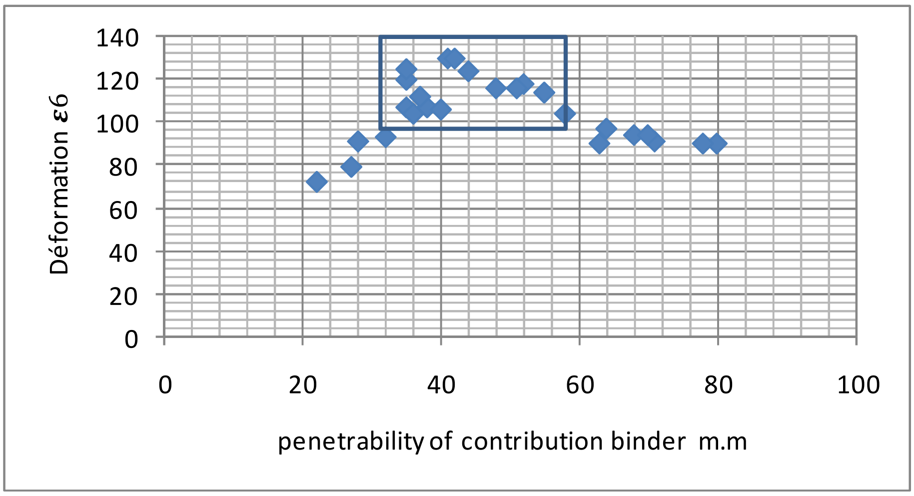

Figure 8: The desirable domain of the penetrability of contribution binder for manufacturing recycled asphalt resist to the fatigue

7 Conclusion

The mechanical behavior of recycled asphalt, in the areas of fatigue, has been studied in this work, and we conclude the following:

1. A rate of 100% of asphalt aggregate is possible if we can master the choice of a new binder which reproduces a contribution binder compatible with this maximum rate.
2. The temperature must be greater than 140° to ensure remobilization of the old binder and ensure the homogeneity of the contribution binder.
3. The penetrability or the class of the binder has shown that it plays a key role in the mechanical performance of recycled asphalt, Figure 8. Shows the field limit of the penetrability of the contribution binder to produce a recycled asphalt resistant to fatigue. This limit is 33mm inferior and 58mm superior.
4. The choice of binder must be made with caution because it is linked to the rate of asphalt aggregate tablets used. If the higher rate of asphalt aggregates is low, the penetrability of new bitumen used must be low, and the contrary for the high rates, in order to produce a contribution binder compatible with the percentage of used asphalt aggregates.
5. The modeling by the use of the methods of the plans of experience allows you to determine the equation (1) by which can estimate the fatigue for different rates of the factors studied.
6. This study we a allows to control the preparation of the binder of intake as amended (old binder+ new binder) with the goal of having the same characteristics of the binder of recycled asphalt. This facilitates the manufacture of recycled asphalt with a high rate of aggregates of asphalt in central.
7. At low temperature the bitumen has a brittle behavior.
8. We can avoid the low-temperature cracking if one uses a bitumen of high rank, that is to say, a bitumen less "hard", and therefore less "brittle" at low temperature.
9. The bitumen ideal must therefore be both the less likely possible to the phenomena of the fatigue.

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