Institut des Sciences & Techniques Appliquées
University of Tlemcen
جامعة تلمسان

UNIVERSITY OF TLEMCEN

THE INSTITUTE OF TECHNICAL AND APPLIED SCIENCES (ISTA)

Chapter 3: Concrete formulation methods

Dr. BRIXI Nezha Khedoudja
Email : Nezhakhedoudja.brixi@univ-tlemcen.dz

Academic year : 2024/2025

Concrete formulation methods

The composition of concrete has a significant impact on its properties. Even though we usually know which characteristics we want (such as strength or workability), creating a mix that meets all of them can be challenging. This is because several elements, such as cement, aggregates, water, and admixtures, affect the final result.

La composition du béton a un impact important sur ses propriétés. Même si on sait généralement quelles caractéristiques on recherche (comme la résistance ou la maniabilité), il peut être compliqué de créer un mélange qui les respecte toutes. Cela vient du fait que plusieurs éléments, comme le ciment, les granulats, l’eau et les adjuvants, influencent le résultat final.

Concrete is a mixture whose composition profoundly influences its characteristics; although the desired properties are usually well defined, developing an appropriate concrete mix can prove more challenging. The parameters involved are indeed numerous:

– Project specifications: mechanical characteristics, structural dimensions, reinforcement, etc.

– Concrete mix design methods – Site conditions: application equipment, climate conditions, etc.

– Properties of the concrete: workability, density, durability, appearance, etc.

Thus, the importance of concrete mix design is clear, especially as the required characteristics become more demanding

How to Determine the Composition of Concrete

To achieve the required characteristics of concrete, it is essential to design and optimize its mix according to the specific demands of the structure and its environment. For this reason, the mix design process generally involves two phases:

1. **Estimating the Composition**: This step can be carried out either graphically, using methods such as those of Faury or Dreux, or experimentally, for instance, with the LCPC (Laboratoire Central des Ponts et Chaussées) method by Baron and Lesage.

These various methods aim to maximize concrete compactness, based on Caquot’s theories of granular composition in mixtures, which have been largely confirmed by current knowledge of concrete.

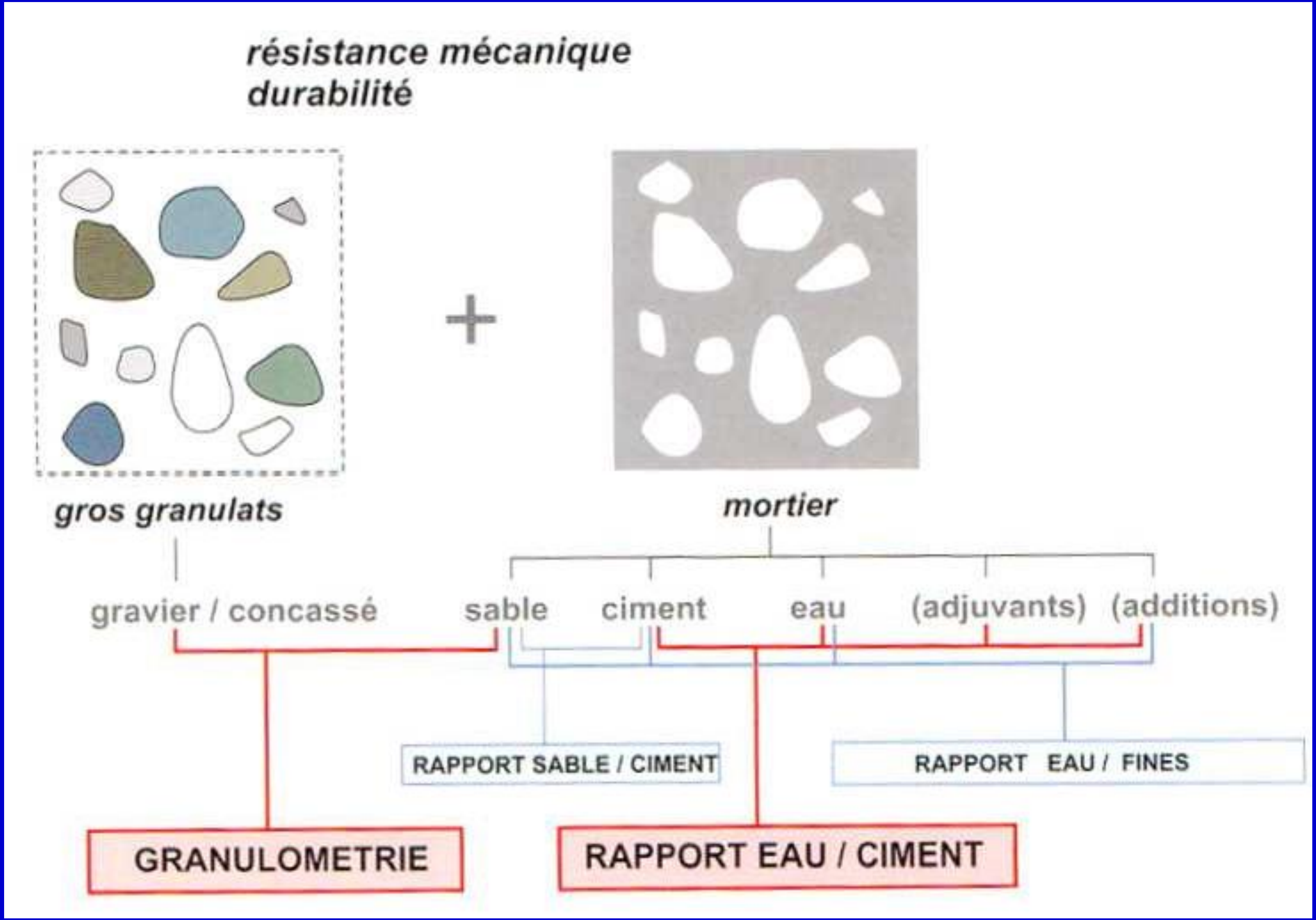
The Dreux diagrams, discussed in the next section, are based on this approach, which emphasizes the "binding function" and, consequently, the concrete’s strength. In this approach, the water-cement ratio (C/W) is calculated using the formula:

$Rb_{28} = G\ Rc\ (C/W – 0,5)$

Rb_{28} ; compressive strength of concrete at 28days (résistance à la compression du béton à 28 jours),

Rc = actual strength of cement (résistance réelle du ciment);

G: coefficient between 0.35 and 0.65.



résistance mécanique
durabilité

gros granulats

\+

mortier

gravier / concassé

sable

ciment

eau

(adjuvants)

(additions)

RAPPORT SABLE / CIMENT

RAPPORT EAU / FINES

GRANULOMETRIE

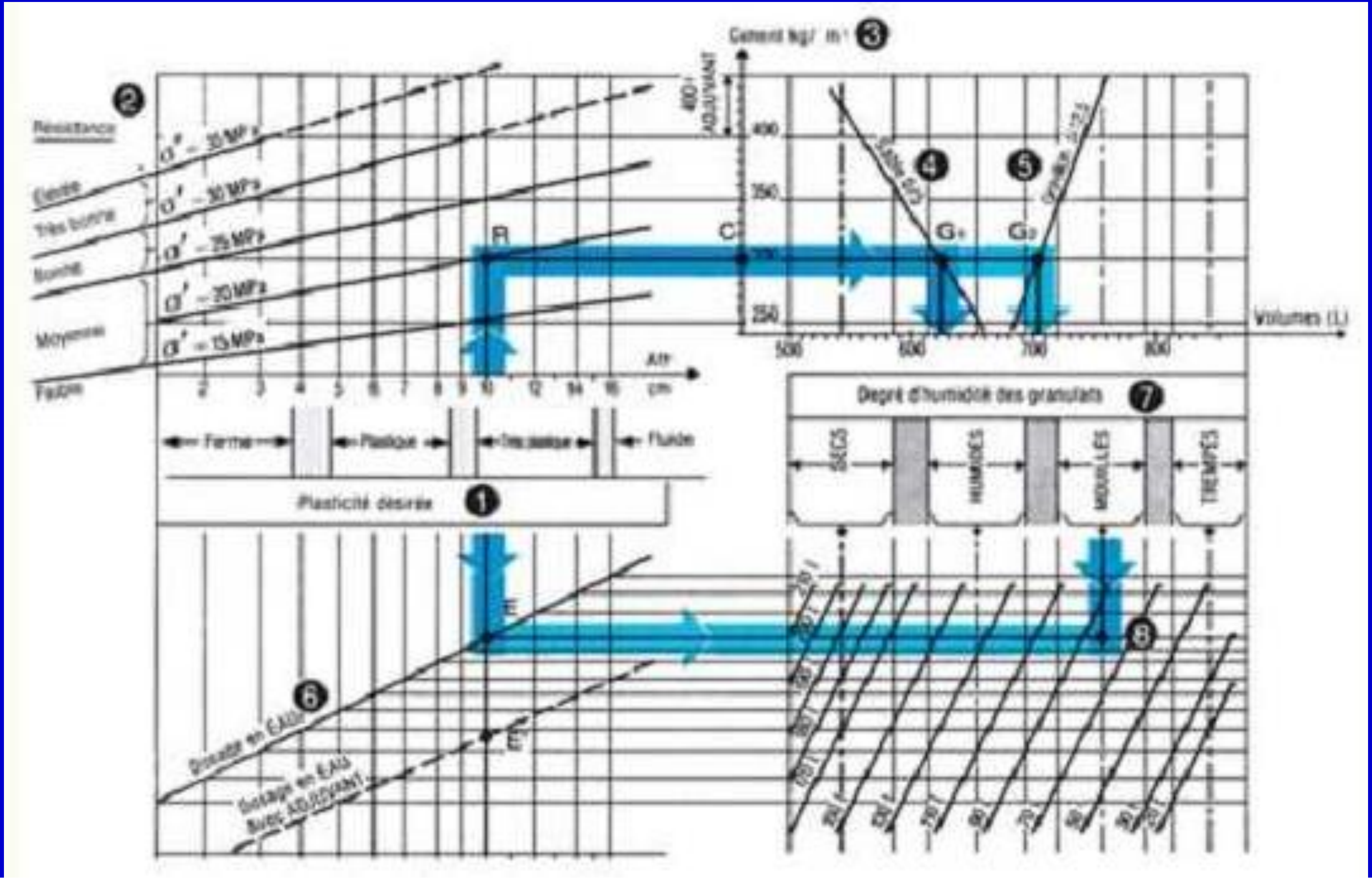
RAPPORT EAU / CIMENT

Dreux Abacus Method

Dreux Abacus Method: The Dreux abacuses provide a practical approach to designing a concrete mix that meets specific objectives. It must, as emphasized, be subjected to experimentation to refine the indicated proportions.

The compressive strength of concrete
The application scope of the abacuses is for ordinary concretes with a 28-day compressive strength ranging between 15 MPa and 40 MPa.

CASE OF A FINE CONCRETE = 12.5 mm (Abacus No. 1).
The objective is:
A highly plastic concrete (slump of 10 cm)
A medium compressive strength: approximately 20 MPa



Cement (class 42.5) .... 300 kg/m³
Sand 0/5 mm in a dry state .... 625 liters
Gravel 5/12.5 mm .... 705 liters

Water dosage – Point E

It is assumed that the aggregates are "wet."

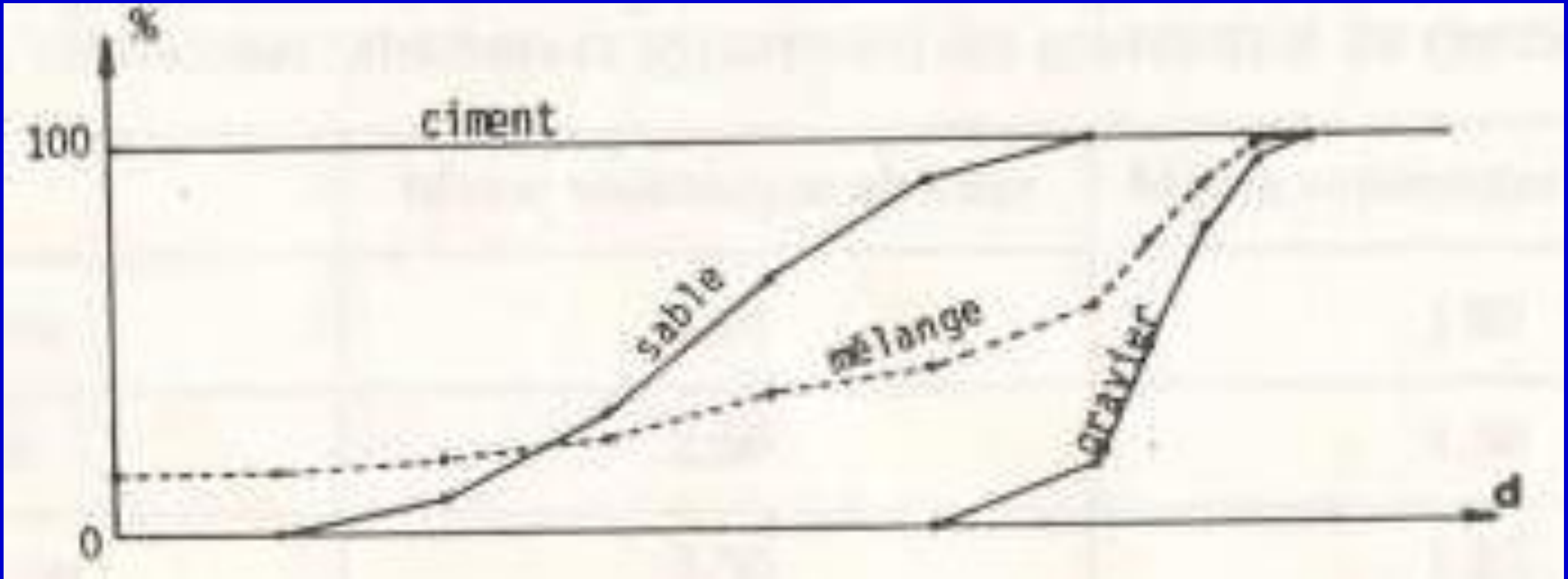
The reading on the grid indicates approximately 80 liters of water to be added.

2. **Bolomey method** :

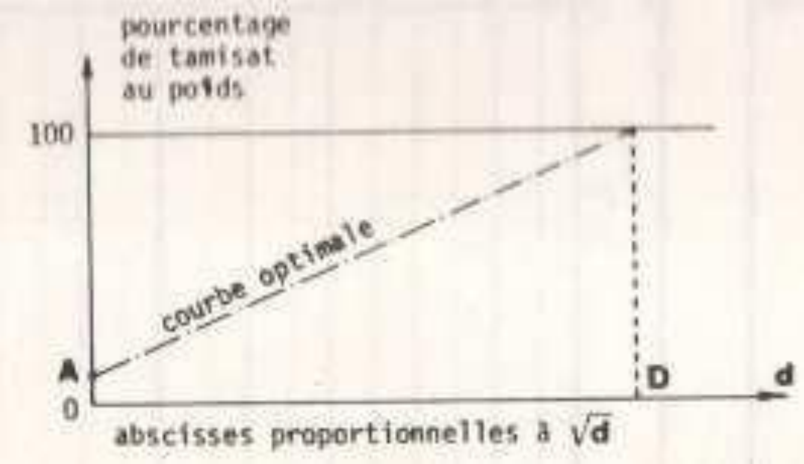
The Bolomey method has the merit of paving the way for concrete studies. However, it can only be applied to aggregates with an absolute density between 2.5 and 2.7 kg/m³, which are, incidentally, the most common aggregates.

The principle of the method consists of:

- Determining the **optimal curve for the dry mix of components**,
- Calculating the percentages of these constituents that allow for a **dry mix whose** curve is as close as possible to the optimal curve,
- Deriving the composition of one cubic meter of concrete.



optimal curve :



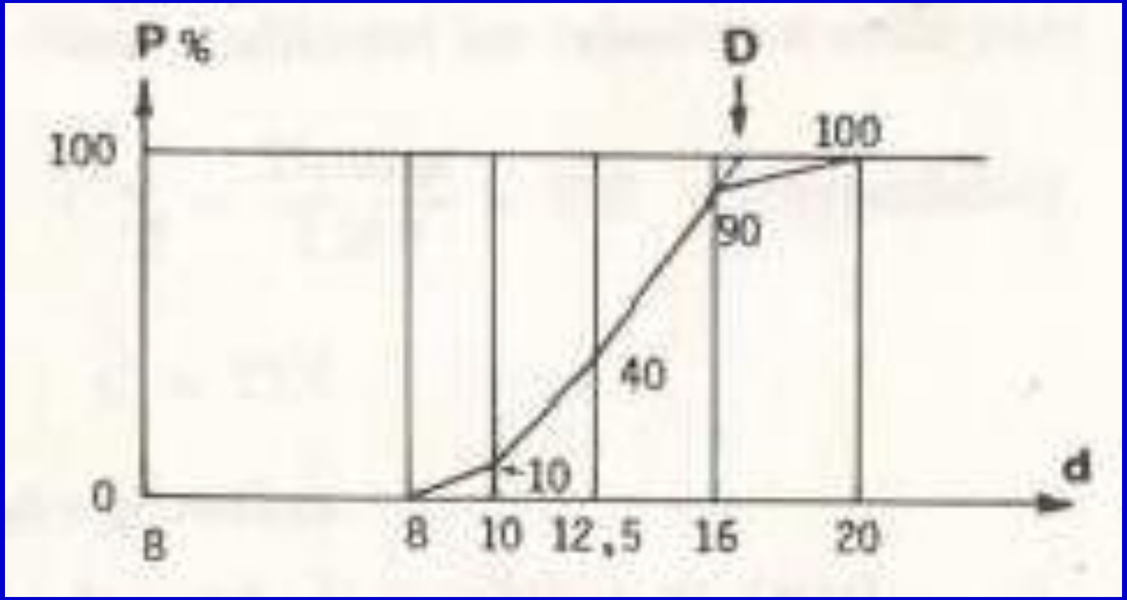
$$P = A + (100 - A)\sqrt{d/D}$$

A and D are constants. The equation is in the form of a straight line: y = a + b . x, which passes through the points: d = 0 and P = 0;
d = D and P = 100.

A : Represents the percentage of very fine elements contained in the dry mix, which affect the workability of the concrete. The value of this constant depends on the desired consistency of the concrete and the origin of the aggregates.

Concrete Consistency	Rolled aggregates	Crushed aggregates
Compacted concrete	6 ÷ 8	8 ÷ 10
Reinforced concrete	10	12 ÷ 14
Caste concrete	12	14 ÷ 16

D :It is the size of the sieve that would just be sufficient to allow all the aggregates to pass through.



In the following example, the value of D is between 16 and 20 mm. To obtain it, simply extend the second-to-last section of the curve of the largest aggregate.

It is noted that this construction is only possible when there is a grading tail (a very common case); if the point were located beyond two-thirds of the interval 16-20 where the line of 20 lies, then 20 would be the value retained for D.

Calculation of the percentage of constituents

:

cement :

$$c\ (\%) = \frac{\text{Mass of cement}}{\text{Total mass of dry components}} \times 100$$

Aggregates:

A graphical method called the "Joisel Method"

If we consider the simplest case, a mix of two aggregates (d1/d2); (d3/d4), the curves drawn show that only 3 cases are possible:

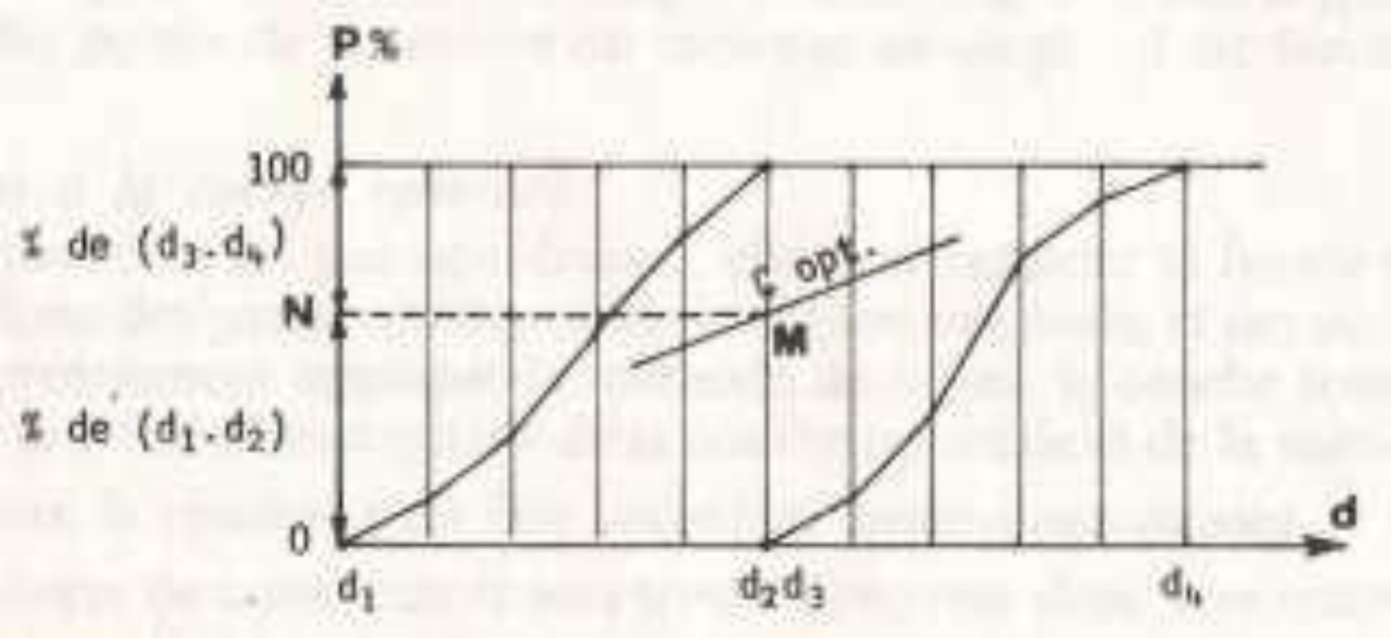
d_3 coincides with d_2 : juxtaposition of the two aggregates,
d_3 to the left of d_2 : partial superposition
d_3 to the right d_2 : discontinuity of the two aggregates,

How to do it ?

The Joisel method is based on drawing a parallel to the y-axis. Let’s take the three cases successively:

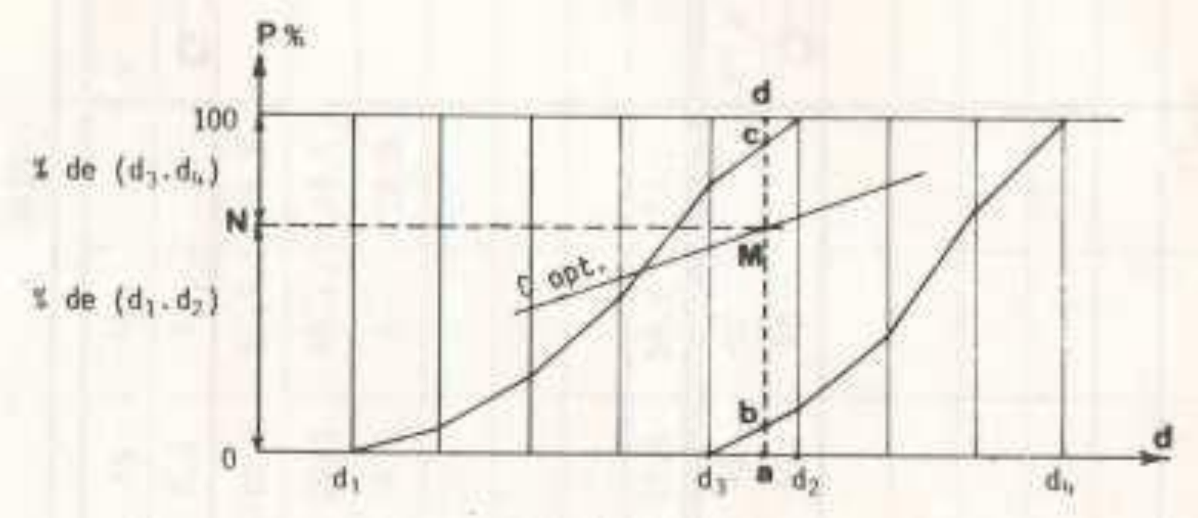
1- Juxtaposition of the two curves: the vertical here is the ordinate corresponding to d2d3. This vertical cuts the optimal curve at a point M, which, when transferred to N on the ordinate scale, determines two segments."

- $\overline{ON}$: % of the aggregate d1d2, or % of components with a dimension < d_2
- $\overline{N100}$: % of the aggregate d3d4, or % of everything greater than d2



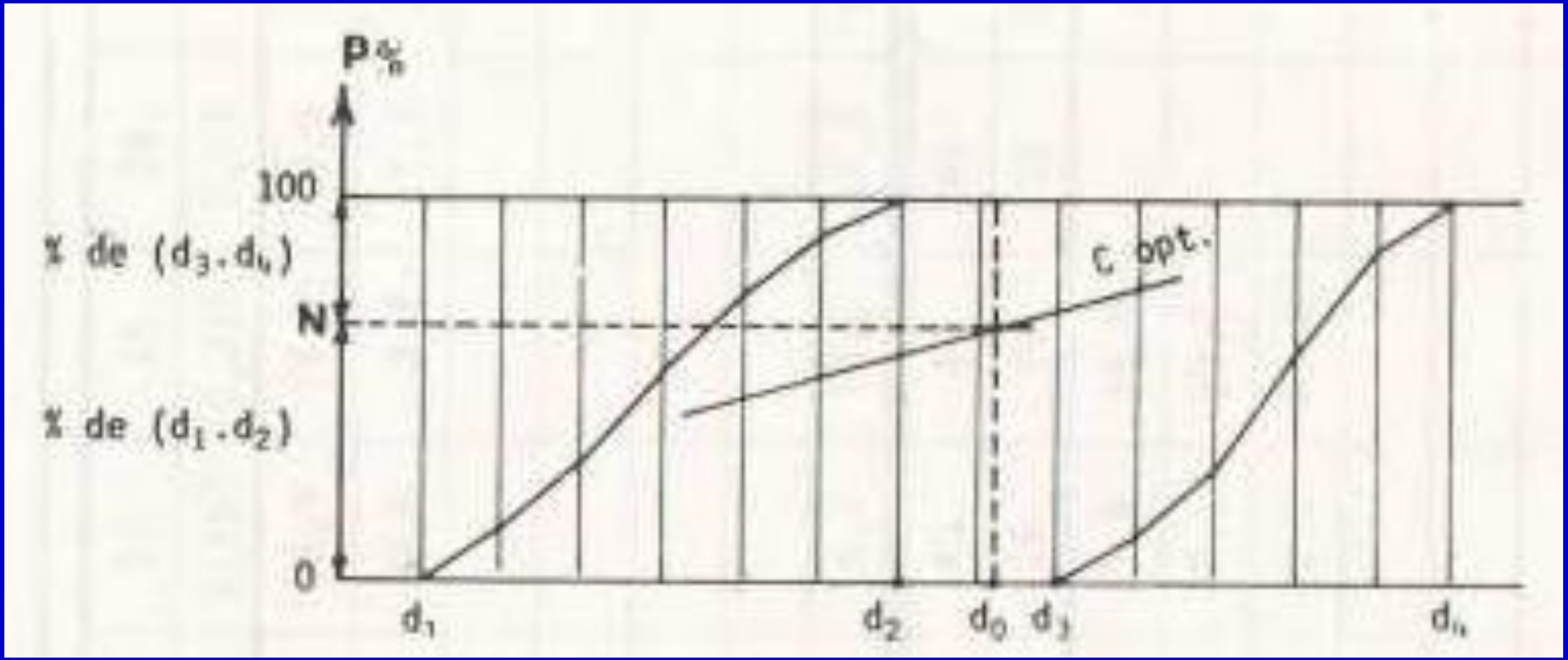
2- Partial superposition of the two curves: The vertical is placed at the abscissa 'd0' such that for this sieve size, the % of the coarse element passing is equal to the % of the finer element retained (ab = cd). M and N have the same meaning as previously.

It is important to place the vertical 'd0' accurately because the ordinate of the intersection point of the optimal curve and this vertical depends on its abscissa. The method involves moving a ruler until the two segments appear equal. In case of lack of precision, it is preferable to resort to a graphical construction. The principle is to fold the lower half-plane onto the upper half-plane around the horizontal XX' (50%). The segments will intersect precisely at the desired point, especially if the angle is large.



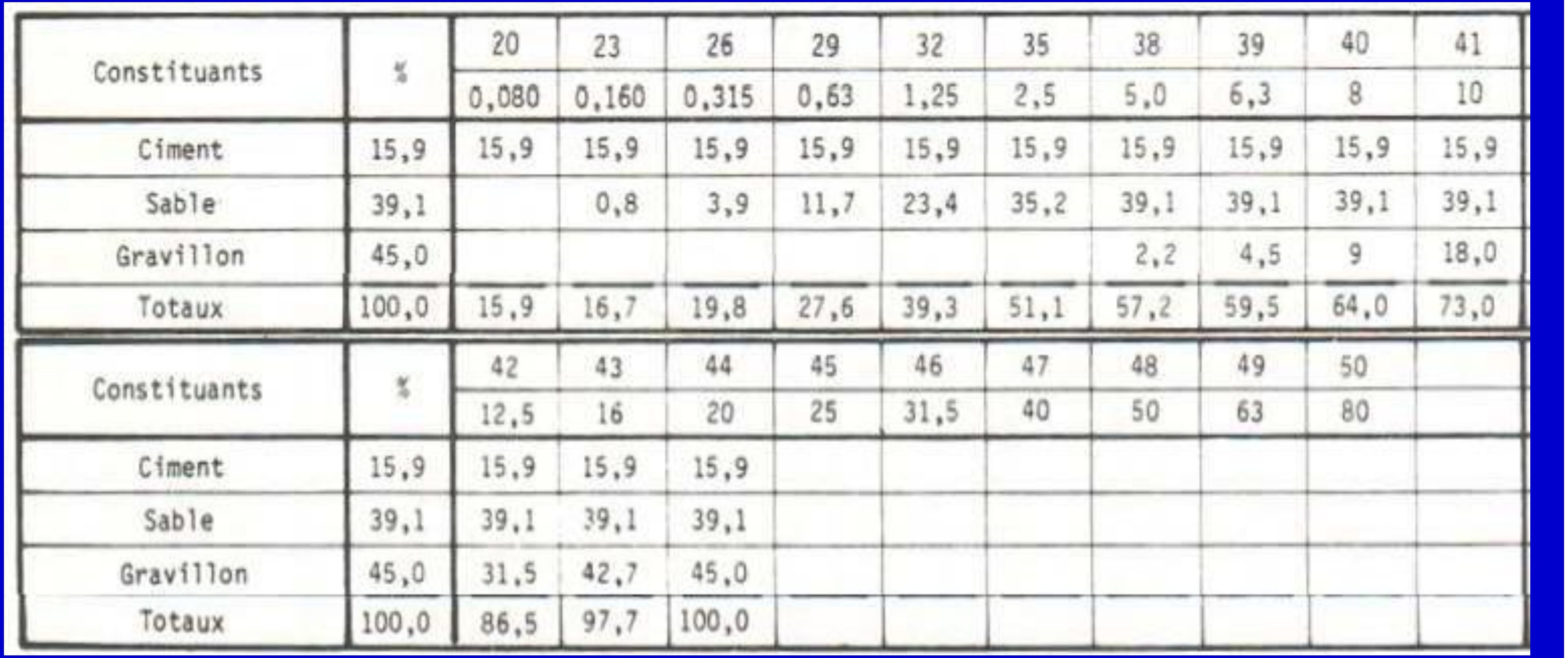
3- Discontinuity between the two curves: the vertical is at the abscissa point". :

$$d_0 = \frac{d_2 + d_3}{2}$$



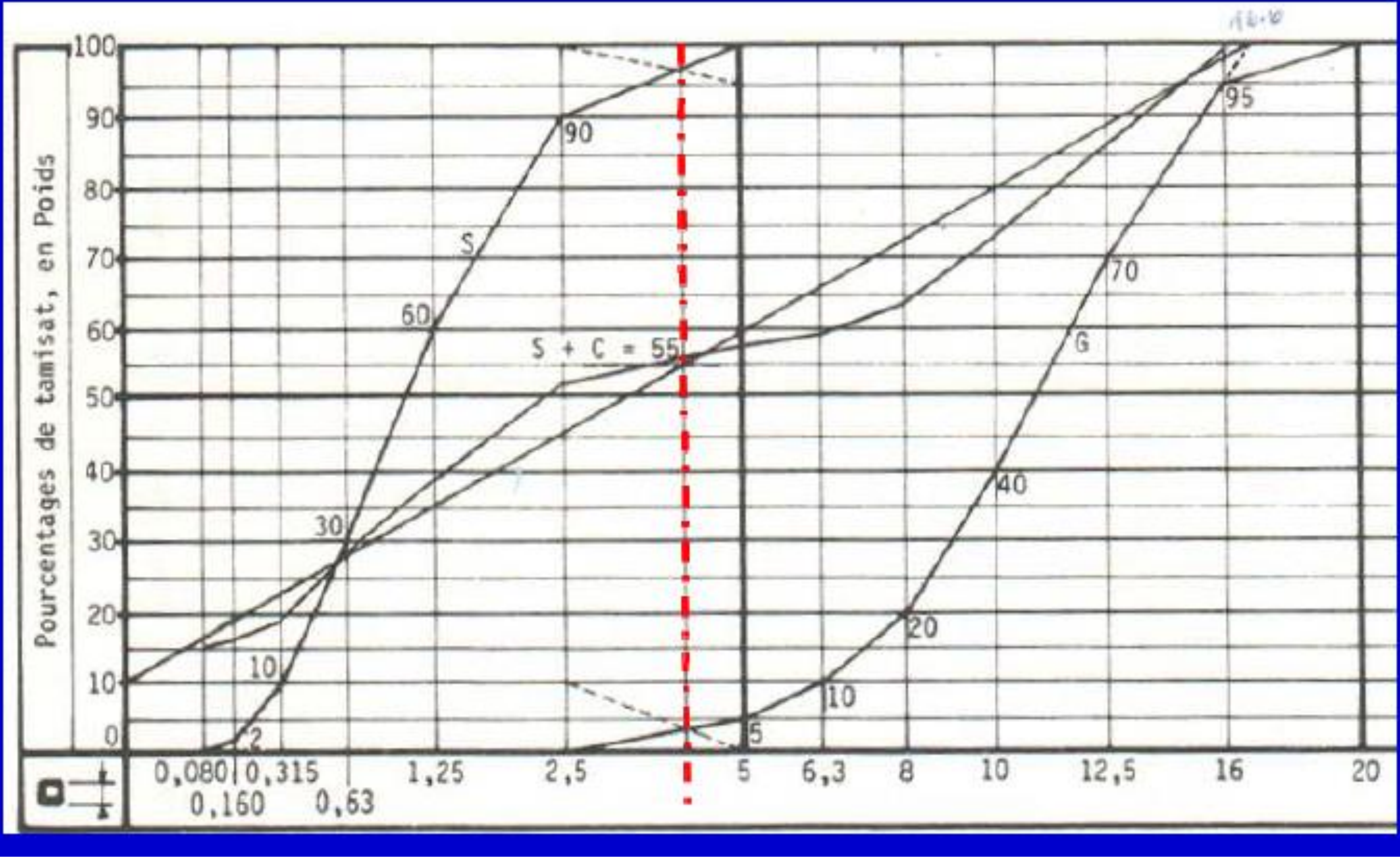
Determination of the mix curve:

The percentages will be determined by calculation without the need for a new sieve analysis. The percentage of cement passes through all the sieves. The percentage of the sieved material of the aggregates is calculated for each sieve based on the percentages of sieved material of each aggregate and the percentage of the aggregate in the mix. The percentage of the sieved material of the mix is the cumulative total of all these separately calculated sieved materials for each aggregate."



Constituants	%	20	23	26	29	32	35	38	39	40	41
		0,080	0,160	0,315	0,63	1,25	2,5	5,0	6,3	8	10
Ciment	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9	15,9
Sable	39,1		0,8	3,9	11,7	23,4	35,2	39,1	39,1	39,1	39,1
Gravillon	45,0							2,2	4,5	9	18,0
Totaux	100,0	15,9	16,7	19,8	27,6	39,3	51,1	57,2	59,5	64,0	73,0

Constituants	%	42	43	44	45	46	47	48	49	50	
		12,5	16	20	25	31,5	40	50	63	80	
Ciment	15,9	15,9	15,9	15,9							
Sable	39,1	39,1	39,1	39,1							
Gravillon	45,0	31,5	42,7	45,0							
Totaux	100,0	86,5	97,7	100,0							


Pourcentages de tamisat, en Poids
100
90
80
70
60
50
40
30
20
10
0
0,080
0,160
0,315
0,63
1,25
2,5
5
6,3
8
10
12,5
16
20
S
G
S + C = 55
2
10
30
60
90
5
10
20
40
70
95
16.10

- **small components**(D < 0,16 mm) :

$\mathbf{W_1 = 0,23} \times$ weight of the dry elements $\mathbf{< 0.16}$

- **coarse elements**(D ≥ 0,16 mm) :

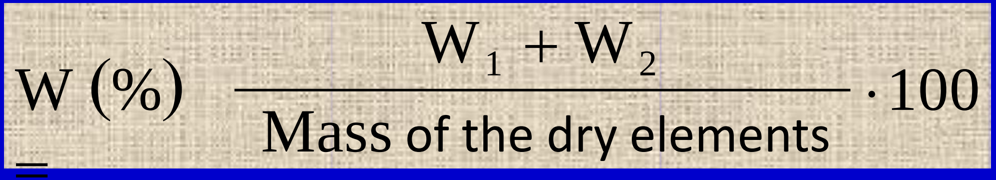
$$W_2 = \frac{k \cdot \text{weight of the dry elements} \geq 0,16}{1,17 \cdot \sqrt[3]{0,16 \cdot D'}}$$

If it is a sieve instead of a mesh, the coefficient 1.17 would be replaced by 1."

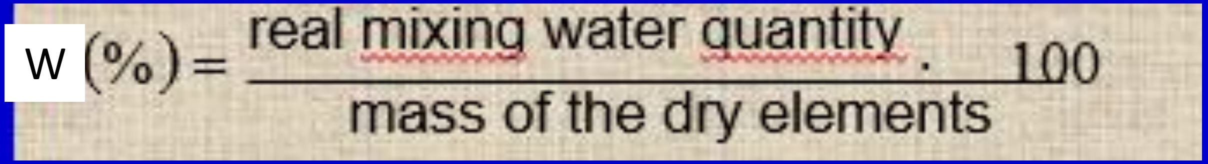
Le coefficient k est tiré du tableau qui suit :

Concrete Consistency	Rolled aggregates	Crushed aggregates
Compacted concrete	0,08	0,095
Vibrated concrete	0,09 ÷0,095	0,1 ÷ 0,11
Caste concrete	0,1 ÷ 0,11	0,12 ÷ 0,13

The amount of water must be expressed as a percentage, like the cement and aggregates, relative to the total dry components.



$$W\,(\%) = \frac{W_1 + W_2}{\text{Mass of the dry elements}} \cdot 100$$



$$W\,(\%) = \frac{\text{real mixing water quantity}}{\text{mass of the dry elements}} \cdot 100$$

The calculation of the weight of the dry components is done assuming the known apparent density of the concrete.

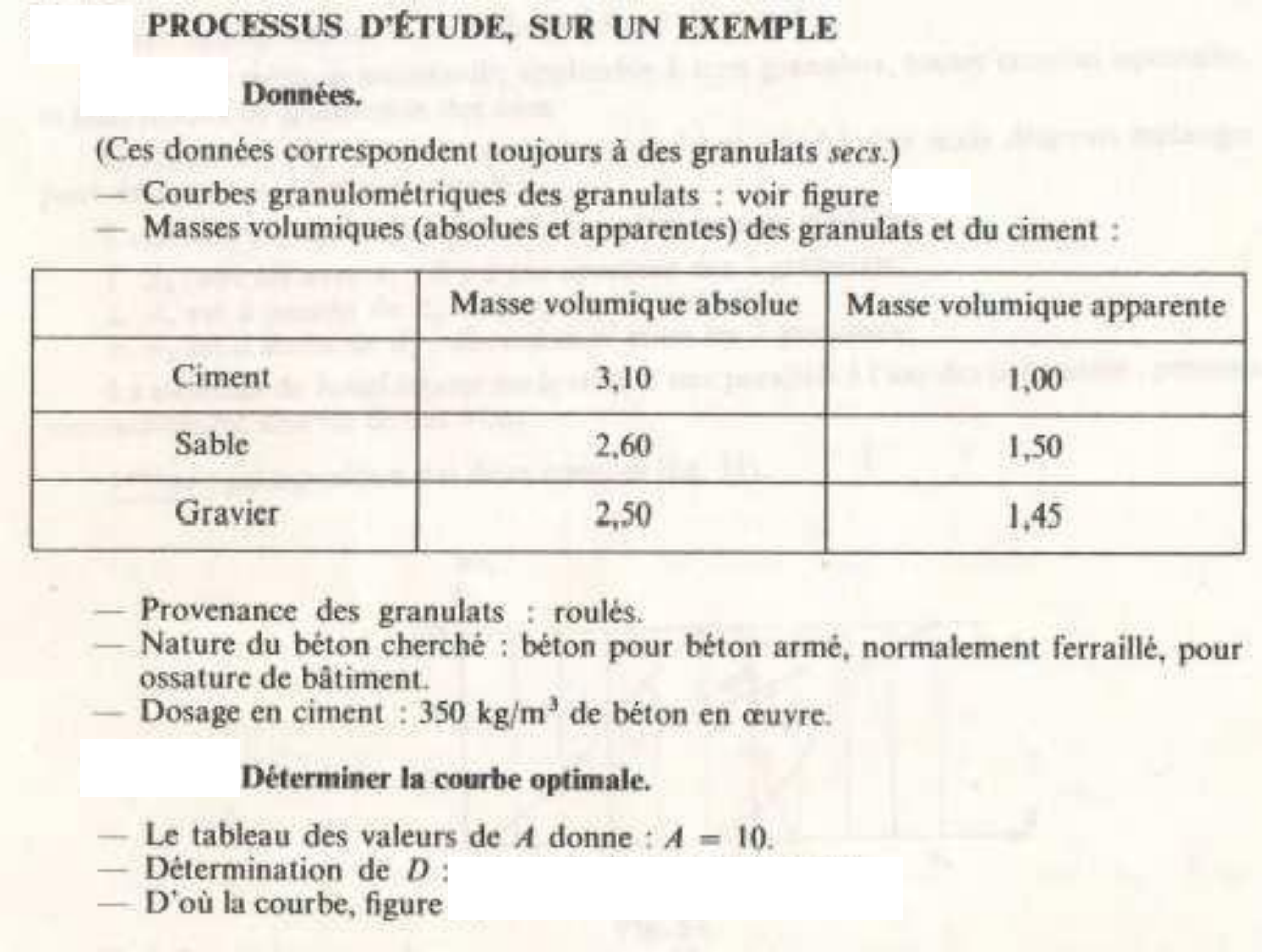
The mass of the dry components = total mass - mass of the mixing water.

The mass of the aggregates = mass of the dry components - mass of the cement.

The mass of each aggregate = % calculated × mass of the aggregates.

This method results in concretes rich in fine components, making them workable and likely to remain as rough formwork. It is used when these quantities are required, with mechanical strength simply needing to be good. It is frequently used for roadworks and for concretes that need to be placed by pumping."

EXAMPLE WITH SOLUTION



PROCESSUS D'ÉTUDE, SUR UN EXEMPLE

Données.

(Ces données correspondent toujours à des granulats *secs*.)

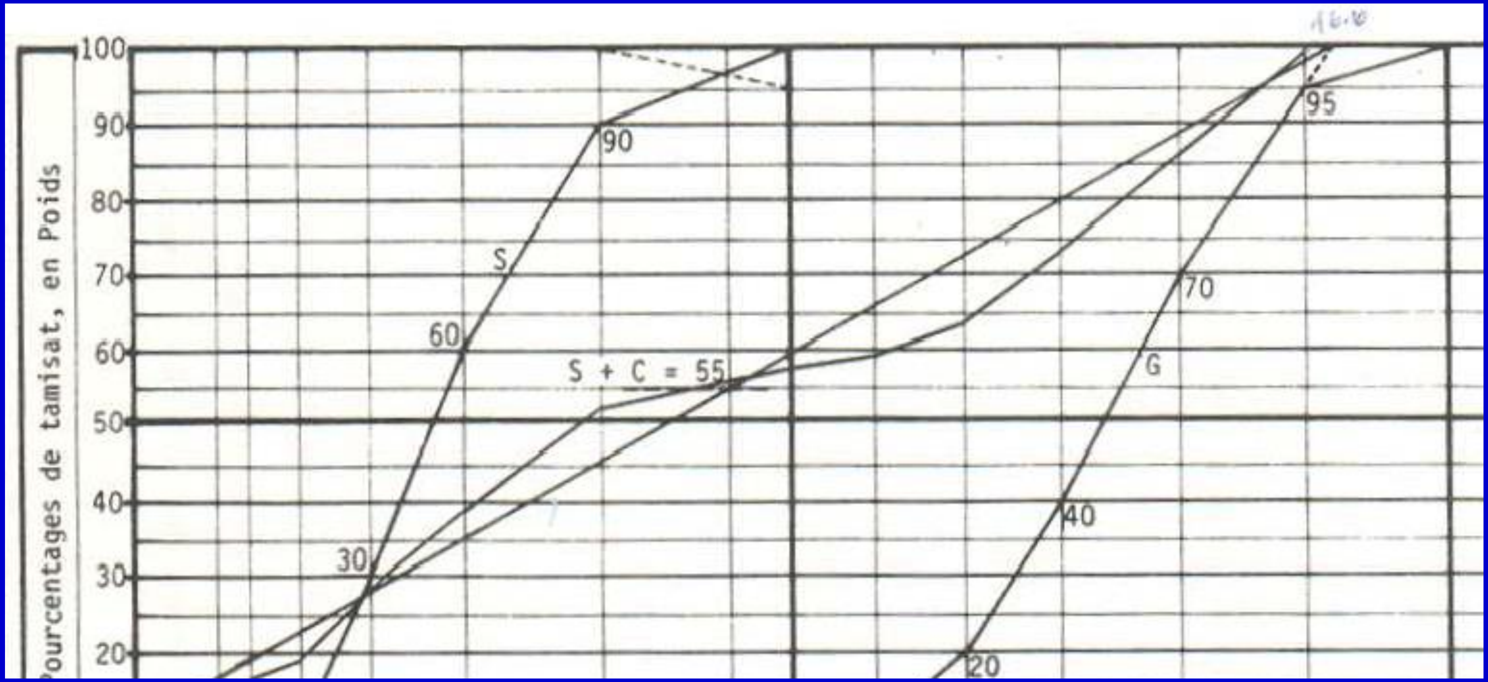
- Courbes granulométriques des granulats : voir figure
- Masses volumiques (absolues et apparentes) des granulats et du ciment :

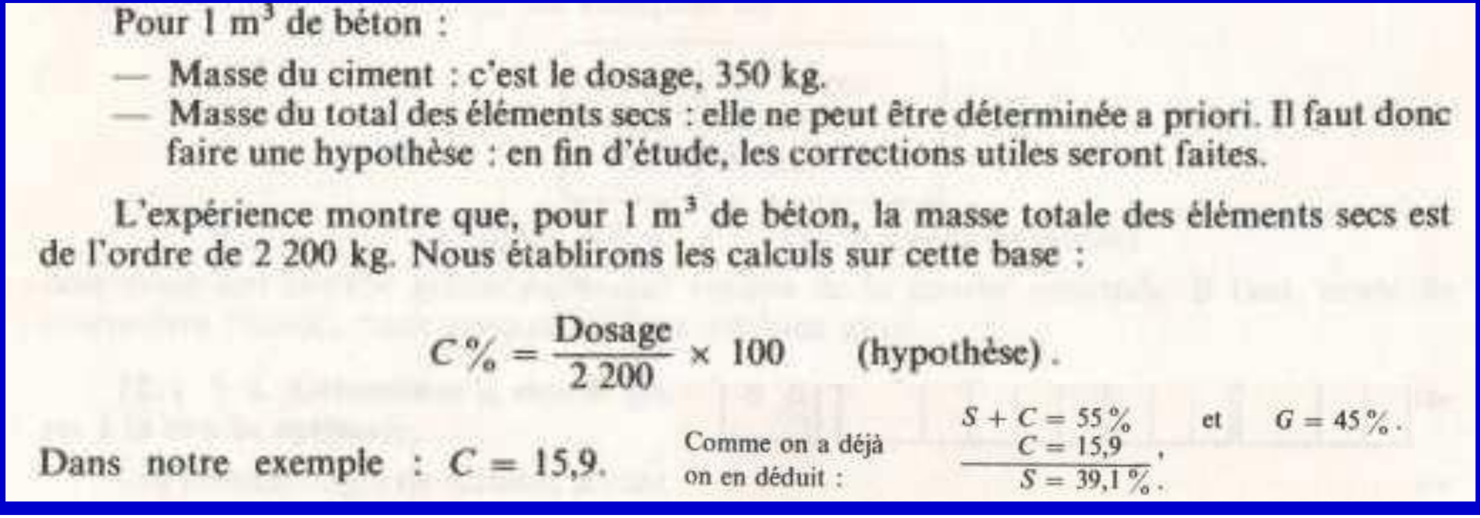
	Masse volumique absolue	Masse volumique apparente
Ciment	3,10	1,00
Sable	2,60	1,50
Gravier	2,50	1,45

- Provenance des granulats : roulés.
- Nature du béton cherché : béton pour béton armé, normalement ferraillé, pour ossature de bâtiment.
- Dosage en ciment : 350 kg/m^3 de béton en œuvre.

Déterminer la courbe optimale.

- Le tableau des valeurs de A donne : $A = 10$.
- Détermination de D :
- D'où la courbe, figure




Pour 1 m^3 de béton :

- Masse du ciment : c'est le dosage, 350 kg.
- Masse du total des éléments secs : elle ne peut être déterminée a priori. Il faut donc faire une hypothèse : en fin d'étude, les corrections utiles seront faites.

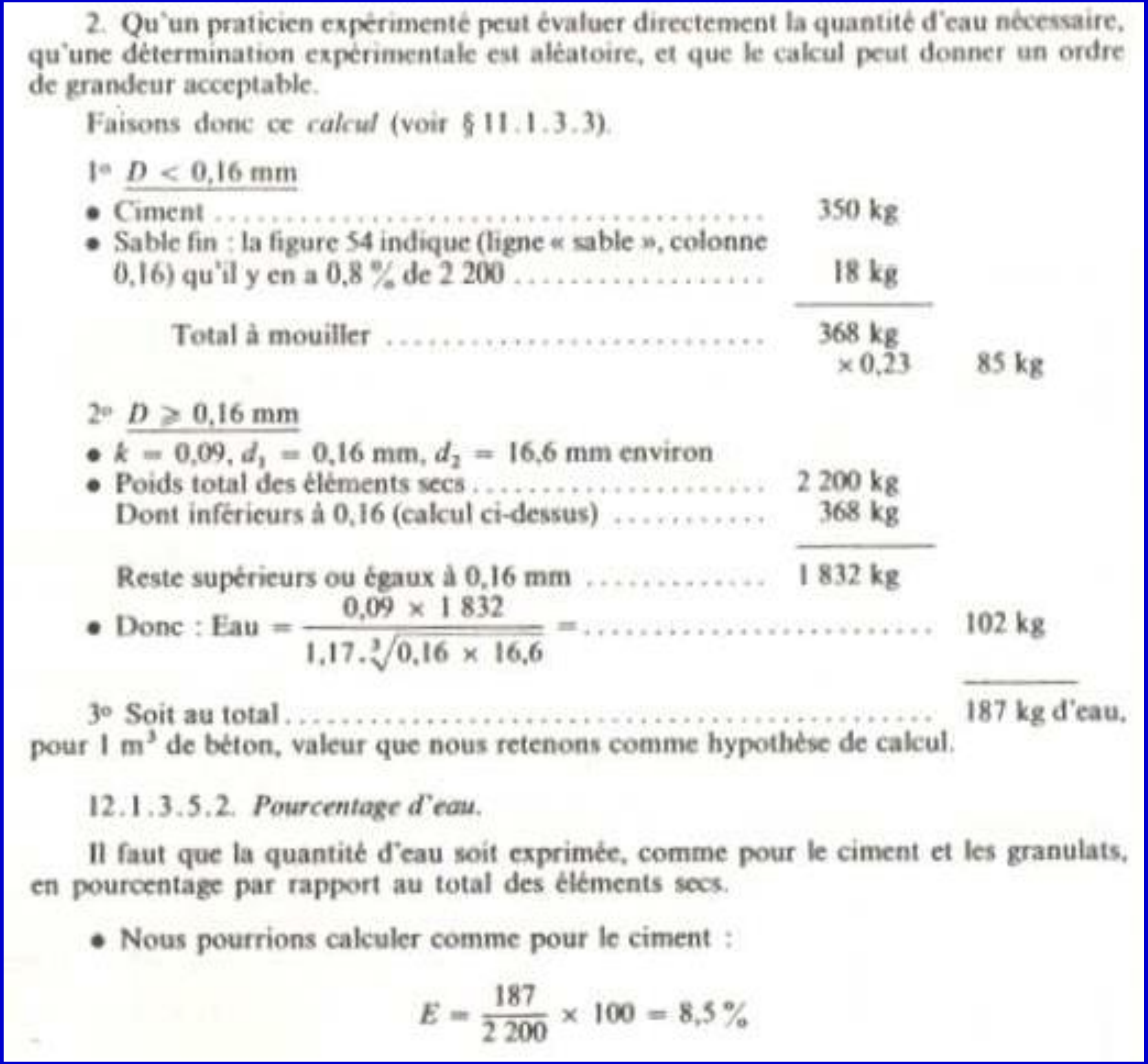
L'expérience montre que, pour 1 m^3 de béton, la masse totale des éléments secs est de l'ordre de 2 200 kg. Nous établirons les calculs sur cette base :

$$C\,\% = \frac{\text{Dosage}}{2\,200} \times 100 \qquad \text{(hypothèse)}.$$

Dans notre exemple : $C = 15{,}9$.

Comme on a déjà on en déduit :

$$\begin{array}{r} S + C = 55\,\% \\ C = 15{,}9 \\ \hline S = 39{,}1\,\%. \end{array} \quad \text{et} \quad G = 45\,\%.$$



2. Qu'un praticien expérimenté peut évaluer directement la quantité d'eau nécessaire, qu'une détermination expérimentale est aléatoire, et que le calcul peut donner un ordre de grandeur acceptable.

Faisons donc ce *calcul* (voir § 11.1.3.3).

1° $\underline{D < 0{,}16 \text{ mm}}$

• Ciment	350 kg	
• Sable fin : la figure 54 indique (ligne « sable », colonne 0,16) qu'il y en a 0,8 % de 2 200	18 kg	
Total à mouiller	368 kg × 0,23	85 kg

2° $\underline{D \geqslant 0{,}16 \text{ mm}}$

- $k = 0{,}09$, $d_1 = 0{,}16$ mm, $d_2 = 16{,}6$ mm environ

• Poids total des éléments secs	2 200 kg
Dont inférieurs à 0,16 (calcul ci-dessus)	368 kg
Reste supérieurs ou égaux à 0,16 mm	1 832 kg

- Donc : Eau $= \dfrac{0{,}09 \times 1\,832}{1{,}17.\sqrt[3]{0{,}16} \times 16{,}6} =$ .... 102 kg

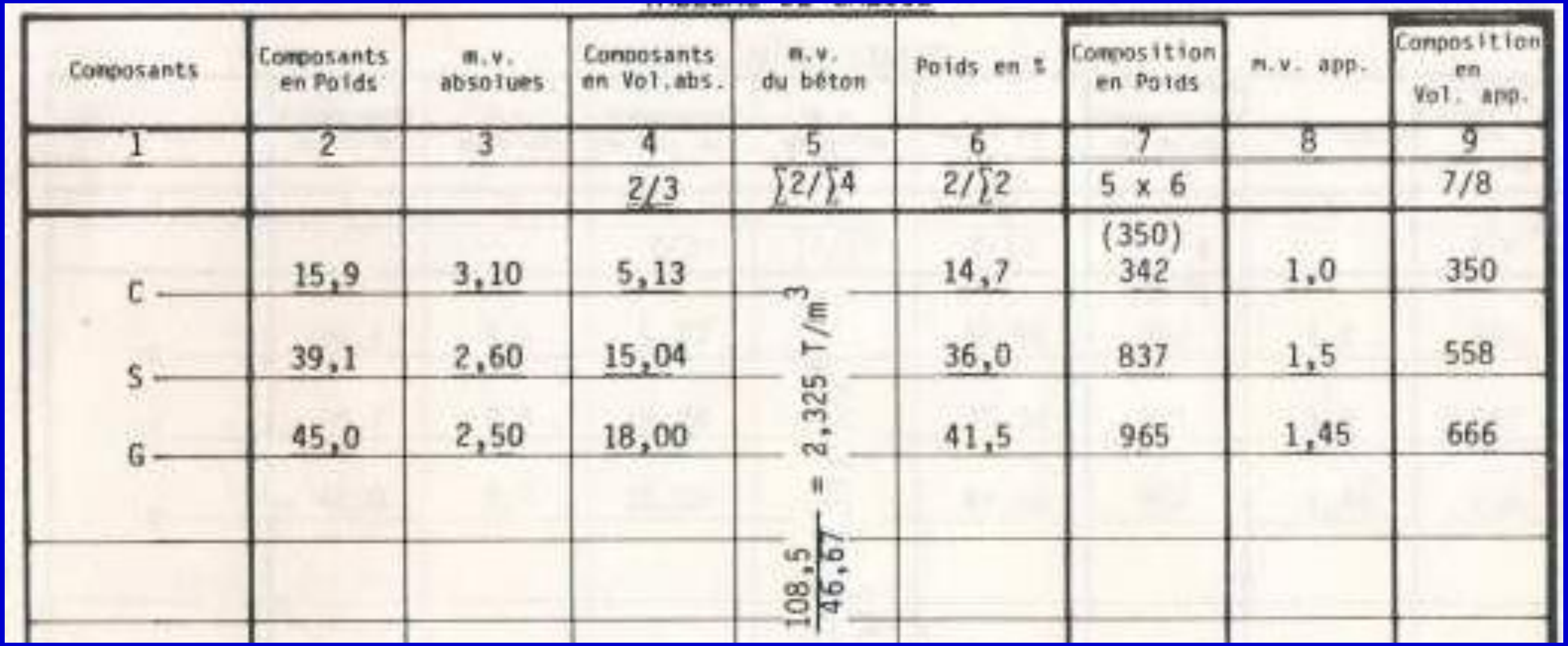
3° Soit au total .... 187 kg d'eau, pour 1 m³ de béton, valeur que nous retenons comme hypothèse de calcul.

12.1.3.5.2. *Pourcentage d'eau.*

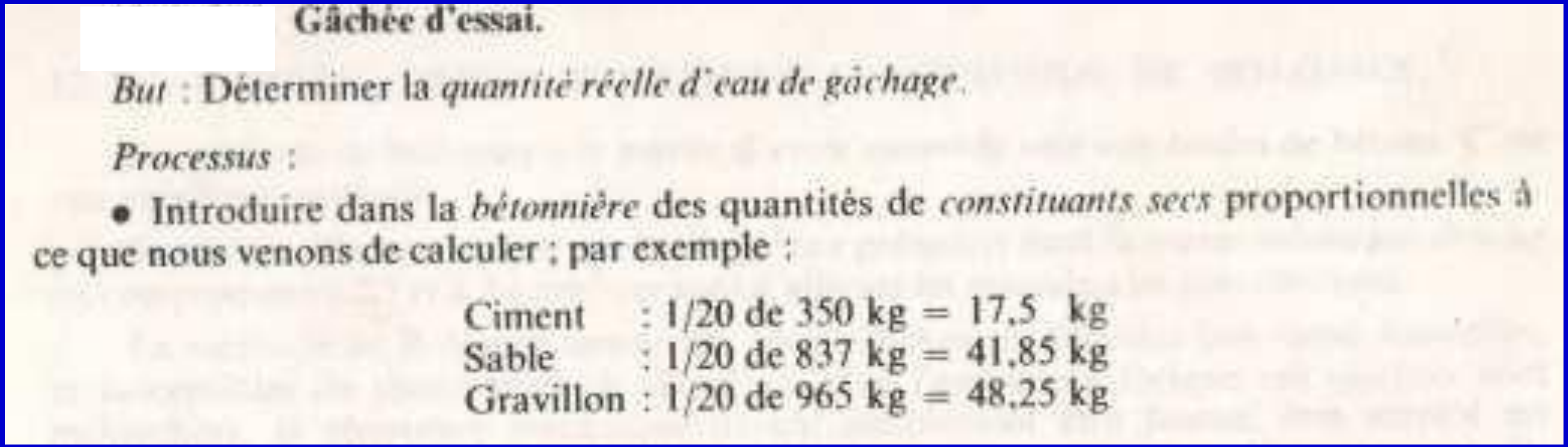
Il faut que la quantité d'eau soit exprimée, comme pour le ciment et les granulats, en pourcentage par rapport au total des éléments secs.

- Nous pourrions calculer comme pour le ciment :

$$E = \frac{187}{2\,200} \times 100 = 8{,}5\ \%$$



Composants	Composants en Poids	m.v. absolues	Composants en Vol.abs.	m.v. du béton	Poids en %	Composition en Poids	m.v. app.	Composition en Vol. app.
1	2	3	4	5	6	7	8	9
			2/3	∑2/∑4	2/∑2	5 x 6		7/8
C	15,9	3,10	5,13	$\frac{108,5}{46,67} = 2,325$ T/m³	14,7	(350) 342	1,0	350
S	39,1	2,60	15,04		36,0	837	1,5	558
G	45,0	2,50	18,00		41,5	965	1,45	666



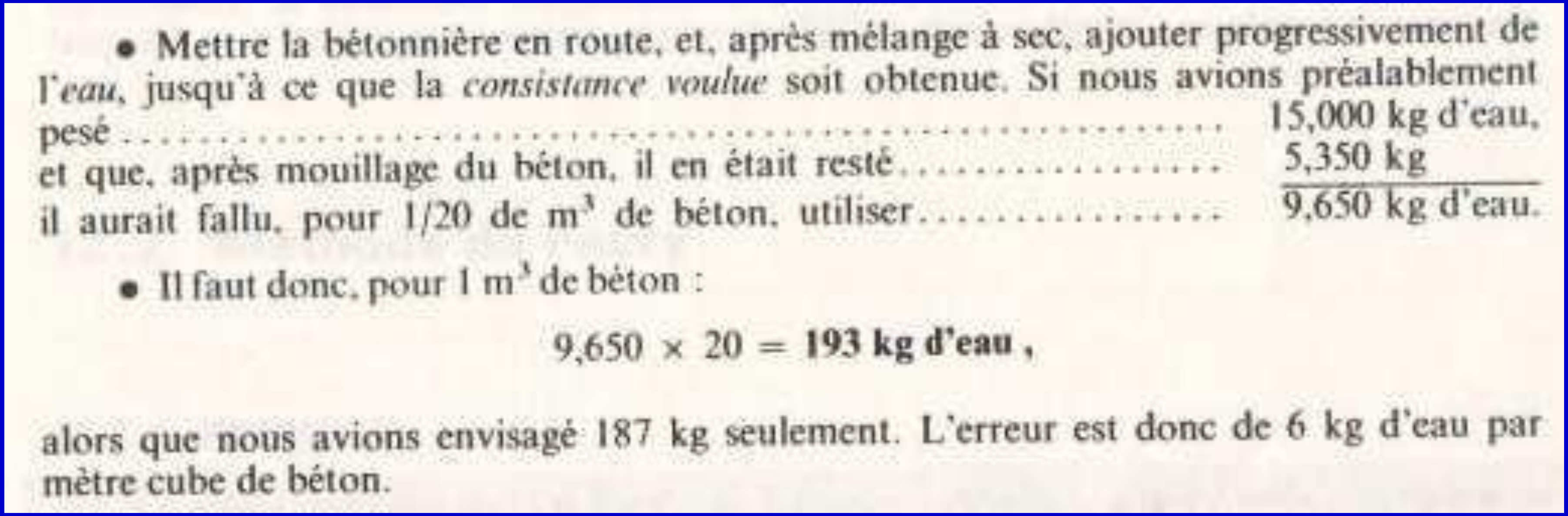
Gâchée d'essai.

But : Déterminer la *quantité réelle d'eau de gâchage.*

Processus :

- Introduire dans la *bétonnière* des quantités de *constituants secs* proportionnelles à ce que nous venons de calculer ; par exemple :

Ciment : 1/20 de 350 kg = 17,5 kg
Sable : 1/20 de 837 kg = 41,85 kg
Gravillon : 1/20 de 965 kg = 48,25 kg



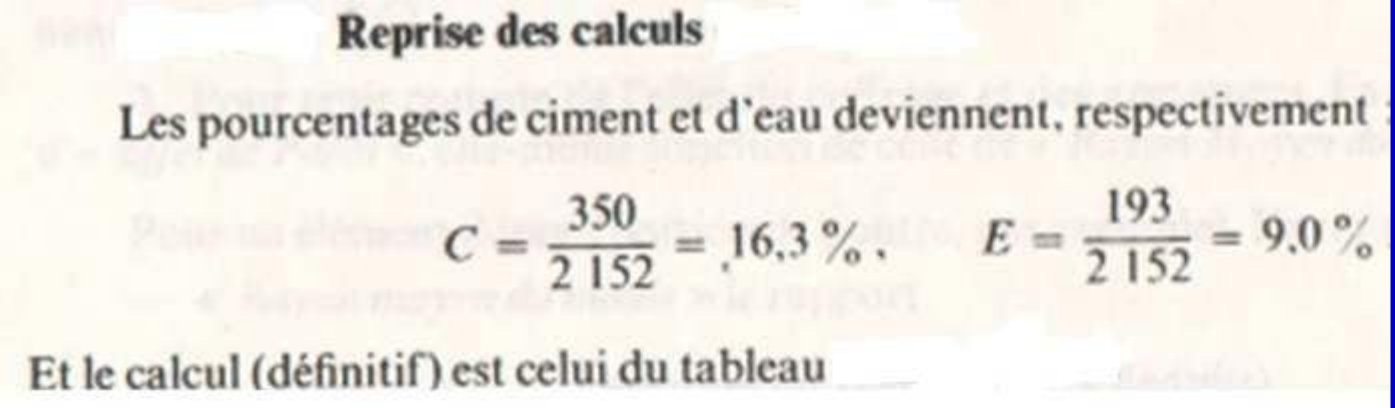
- Mettre la bétonnière en route, et, après mélange à sec, ajouter progressivement de l'*eau*, jusqu'à ce que la *consistance voulue* soit obtenue. Si nous avions préalablement

pesé .... 15,000 kg d'eau,
et que, après mouillage du béton, il en était resté .... 5,350 kg
il aurait fallu, pour 1/20 de m^3 de béton, utiliser .... 9,650 kg d'eau.

- Il faut donc, pour 1 m^3 de béton :

$$9{,}650 \times 20 = \mathbf{193\ kg\ d'eau}\ ,$$

alors que nous avions envisagé 187 kg seulement. L'erreur est donc de 6 kg d'eau par mètre cube de béton.

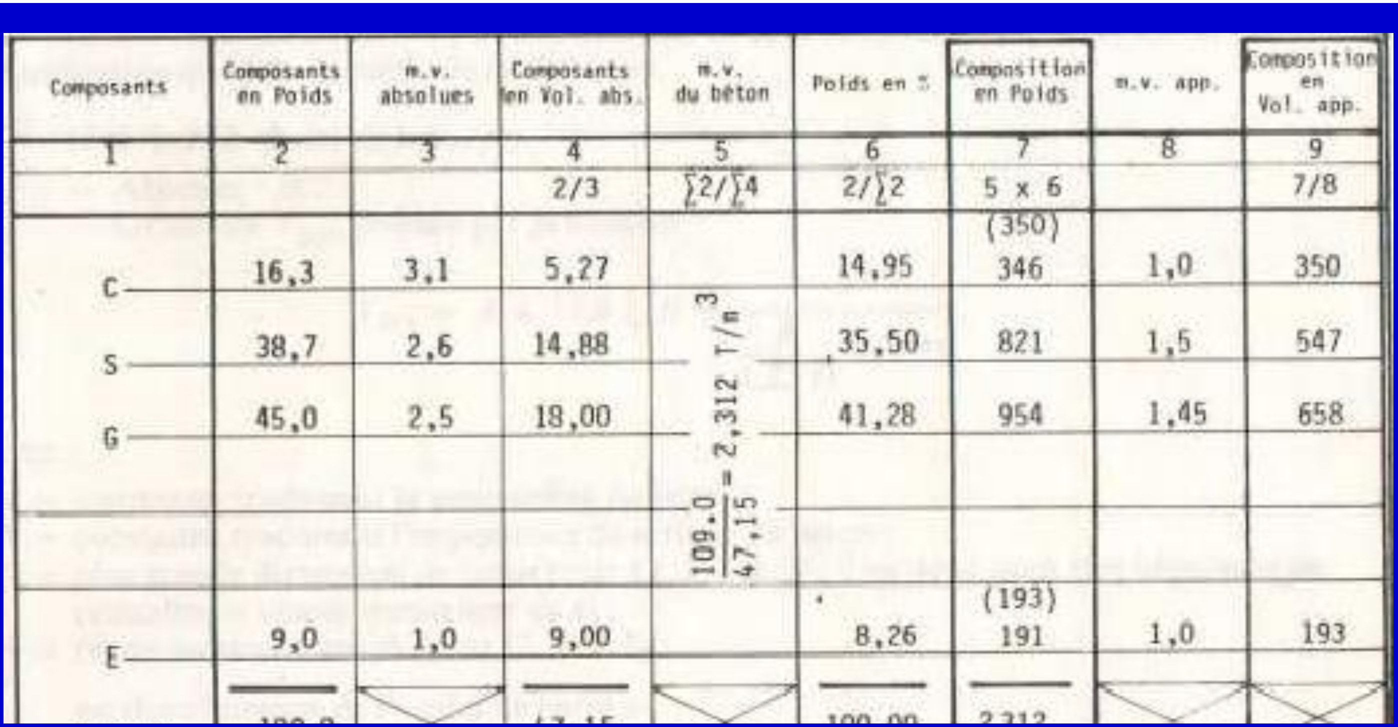


Reprise des calculs

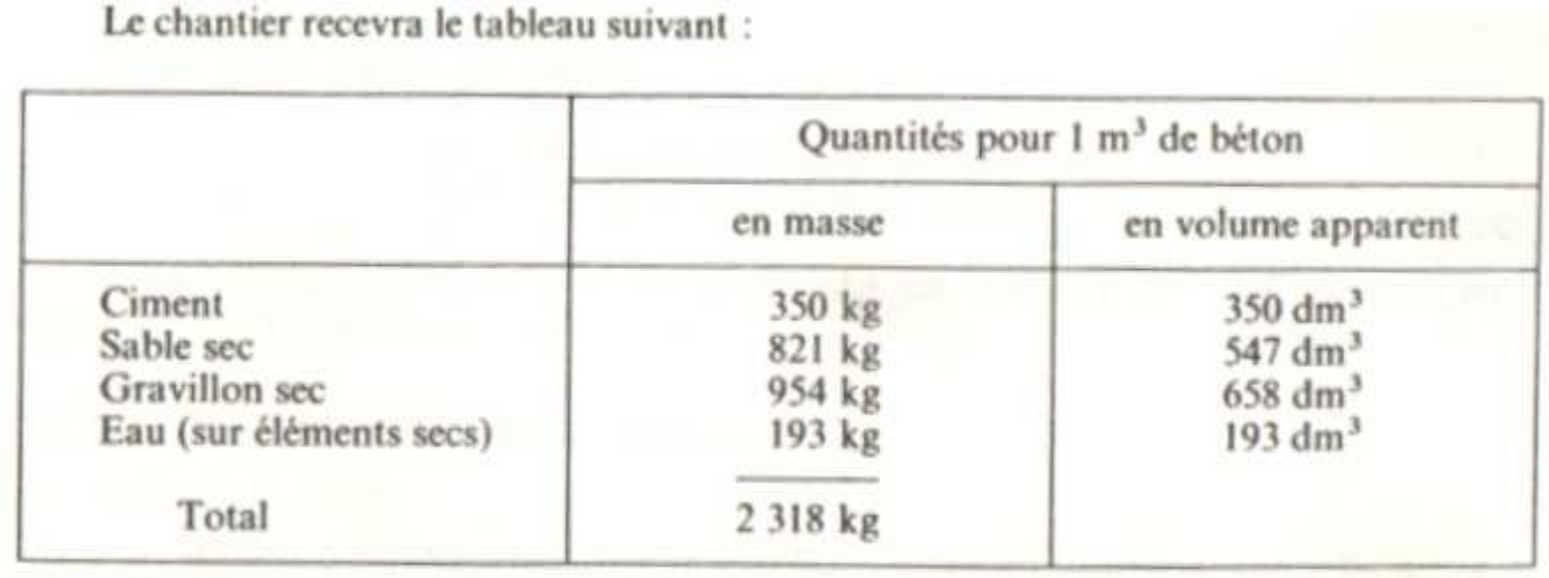
Les pourcentages de ciment et d'eau deviennent, respectivement

$$C = \frac{350}{2\,152} = 16{,}3\ \%\ , \qquad E = \frac{193}{2\,152} = 9{,}0\ \%$$

Et le calcul (définitif) est celui du tableau



Composants	Composants en Poids	m.v. absolues	Composants en Vol. abs.	m.v. du béton	Poids en %	Composition en Poids	m.v. app.	Composition en Vol. app.
1	2	3	4	5	6	7	8	9
			2/3	$\Sigma 2/\Sigma 4$	$2/\Sigma 2$	5 x 6		7/8
C	16,3	3,1	5,27	$\frac{109,0}{47,15} = 2,312$ T/m^3	14,95	(350) 346	1,0	350
S	38,7	2,6	14,88		35,50	821	1,5	547
G	45,0	2,5	18,00		41,28	954	1,45	658
E	9,0	1,0	9,00		8,26	(193) 191	1,0	193



Le chantier recevra le tableau suivant :

	Quantités pour 1 m^3 de béton	
	en masse	en volume apparent
Ciment	350 kg	350 dm^3
Sable sec	821 kg	547 dm^3
Gravillon sec	954 kg	658 dm^3
Eau (sur éléments secs)	193 kg	193 dm^3
Total	2 318 kg	

3. Faury's method :

This method, introduced in 1941, complements the Bolomey method. Faury's method results in concretes with less sand and more gravel. These concretes are stiffer and are suitable for works where excellent workability is not essential. Faury concretes often have superior mechanical strength compared to the corresponding Bolomey concretes.

1. Applicable to all aggregates, regardless of their bulk density
2. Faury studied the effect of voids, which vary with $\sqrt[5]{D}$
3. To account for the effect of the formwork and reinforcement, Faury introduced the concept of wall effect and the average radius of the mold."

$$Ep = \frac{D}{R}$$

$$R = \frac{\text{Concrete volume (excluding steel)}}{\text{Surface area in contact with concrete (formwork + steel)}}$$

It is necessary to verify that :

Nature des granulats	Maximum diameterD ≤			
crushed aggregates	0,8 e	0,7 c	1,6 r	R
Rolled agreggates	0,9 e	0,8 c	1,8 r	1,2 R

e : **Horizontal spacing between horizontal reinforcements,**

c : average concrete cover of reinforcement,

r : average radius of a reinforcement mesh,

$$r = \frac{e \times b}{2 \cdot (e + b)}$$

b : **Vertical spacing between longitudinal reinforcements.**

Optimal curve *:*

This is no longer a straight-line segment but two segments forming a broken line. It is necessary to define: the origin, the endpoint, and the breaking point.

Origin: The point on the horizontal axis corresponding to the sieve with a size of 0.0065 mm. The horizontal axis represents the sieve dimensions (scale), and the vertical axis represents the cumulative percentage of material passing in absolute volume.

Endpoint: The point with an x-coordinate of *D* and a y-coordinate of 100.

Breaking point: The point with an x-coordinate of *D/2*.

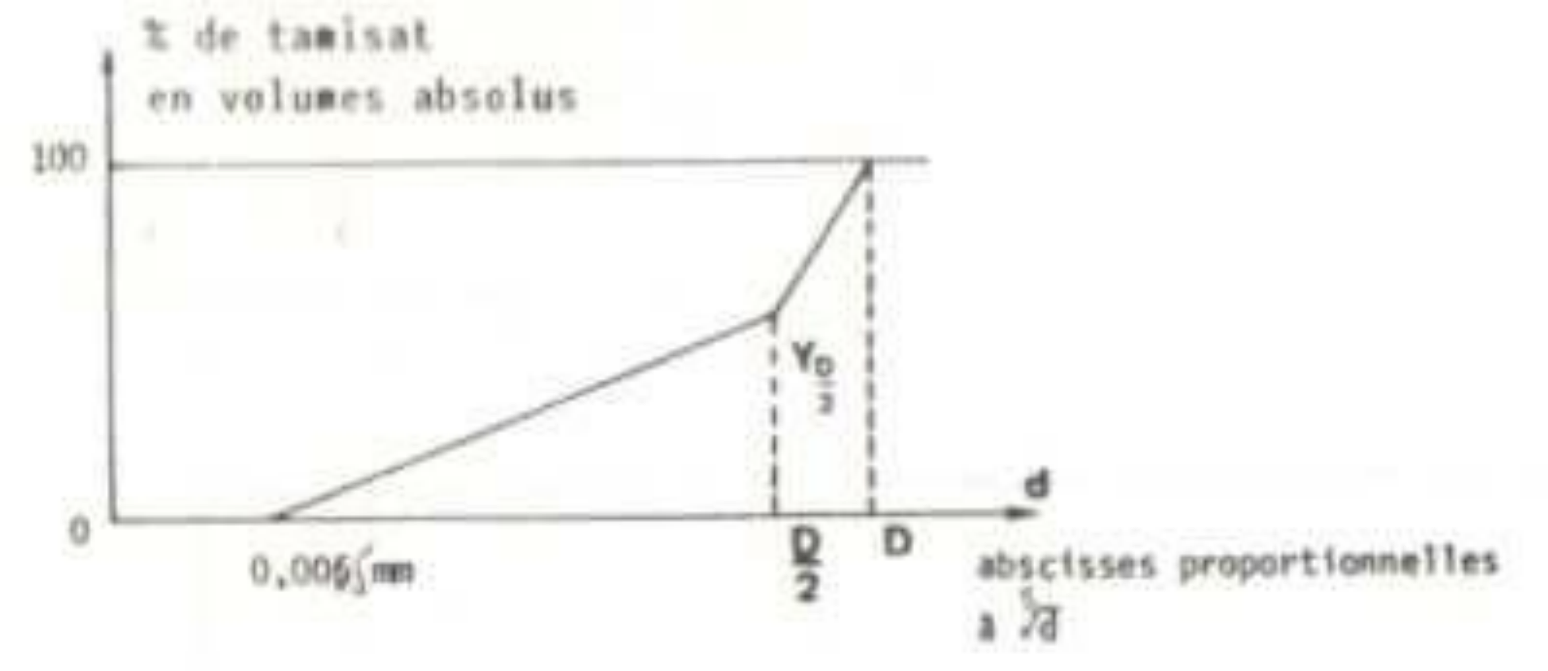
Breaking point: x-coordinate D/2; y-coordinate yD/2 given by the formula:

$$y_{D/2} = A + 17{,}8\sqrt[5]{D} + \frac{B}{\left(R/1{,}25 \cdot D\right) - 0{,}75}$$

If instead of sieves, strainers are used, the breaking point is expressed by:

:

$$y_{D/2} = A + 17\sqrt[5]{D} + \frac{B}{R/D - 0{,}75}$$



A: Constant representing the workability of concrete (see the table below).

B: Constant representing the significance of concrete compaction:
When compaction is particularly energetic, B=1
In all other cases, B=1.5

0

D ≥ 25 mm : *reinforced concrete for buildings and civil engineering structure*

Concrete Consistency	Rolled sand		crushed sand
	Rolled aggregates	Crushed aggregates	
Quite plastic concrete	24 ÷ 26	26 ÷ 28	30 ÷ 32
plastic concrete			32 ÷ 34

26 ÷ 28 28 ÷ 30

25

25 < D ≤ 50 : Lightly reinforced concrete	A = 15 ÷ 20
50 < D ≤ 80 : Rolled aggregates	A = 15 ÷ 20
D > 80 : Rolled aggregates	A = 12

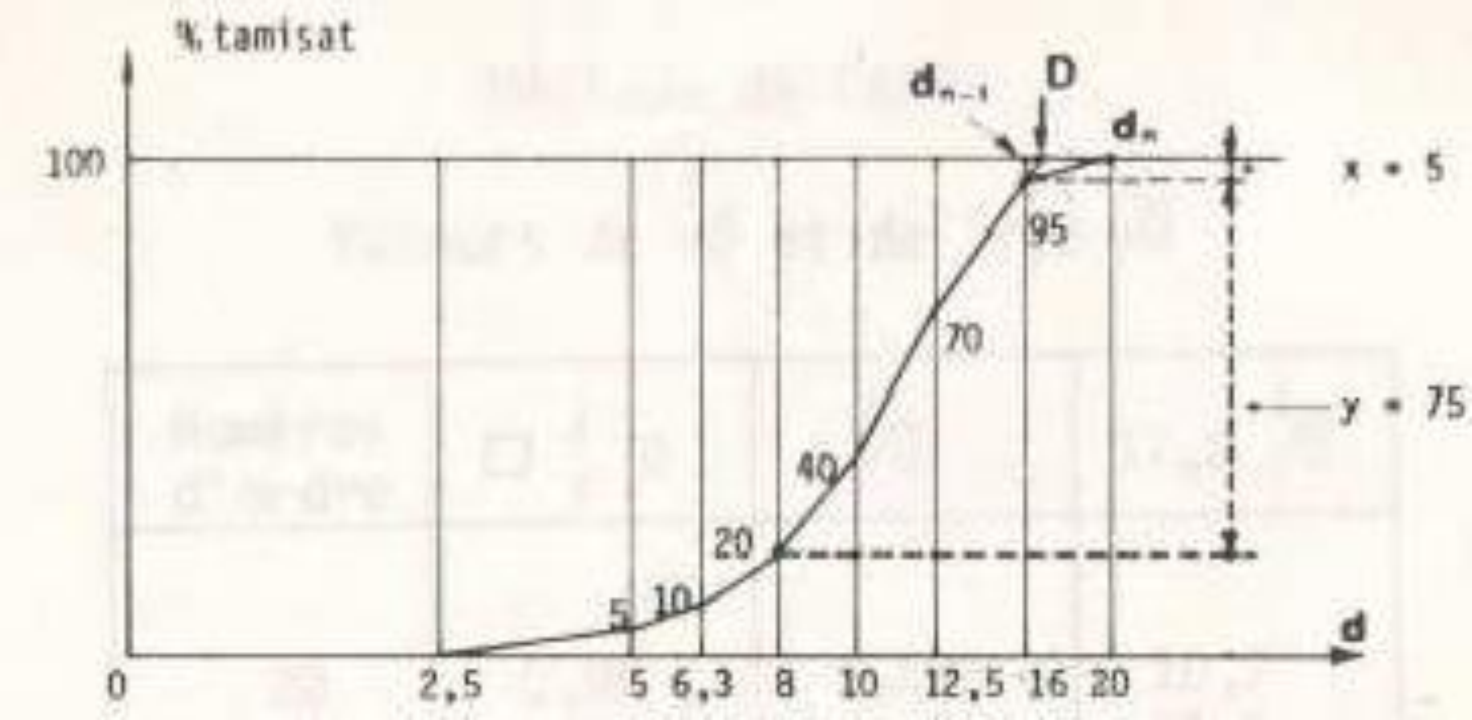
80

Runway concrete	A = 15

Calculation of D :

It is the size of the sieve that would just allow the entire aggregate to pass through. Consider the curve of the largest aggregate of the concrete we are going to study. The value of D is slightly greater than dn−1; that is to say:

$$D = d_{n-1}\left(1+\frac{x}{2y}\right)$$



Calculation of the voids index and the amount of mixing water:

For concrete with a given consistency and given materials, there is a maximum volume of solid materials corresponding to a minimum void; this is given by:

$$n = \frac{K}{\sqrt[5]{D}} + \frac{K'}{\frac{R}{D} - 0{,}75}$$

The usual values of K and K' are given by the following table:

Concrete Consistency	Moyen de mise en œuvre (Implementation Means	Materials Used			K'
		Rolled sand Rolled aggregate	Rolled sand Agg. crushed	crushed.s. Crushed agg	
soft concrete	piquage et damage sans vibration	> 0,34	> 0,36	> 0,38	0,004
normal	Medium vibration	0,26	0,28 0,30	0,30 0,34	0,003
Ferme (stiff)	Intense vibration	0,25 0,27	0,26 0,28	0,28 0,30	0,002
très ferme (very stiff)	Powerful vibration	< 0,24	< 0,25	< 0,27	0,002

In practice, the quantity of water W that should fill the voids is insufficient for convenient processing, so 20 to 30% more water must be added depending on the desired workability:

$1{,}2 \,.\, n \leq W \leq 1{,}3 \,.\, n$ B
Ferme B. Mou (Hard
concrete , soft concrete

Composition by weight of solid components :

In 1 m^3 of concrete, the total absolute volume of solid constituents is 1-W,

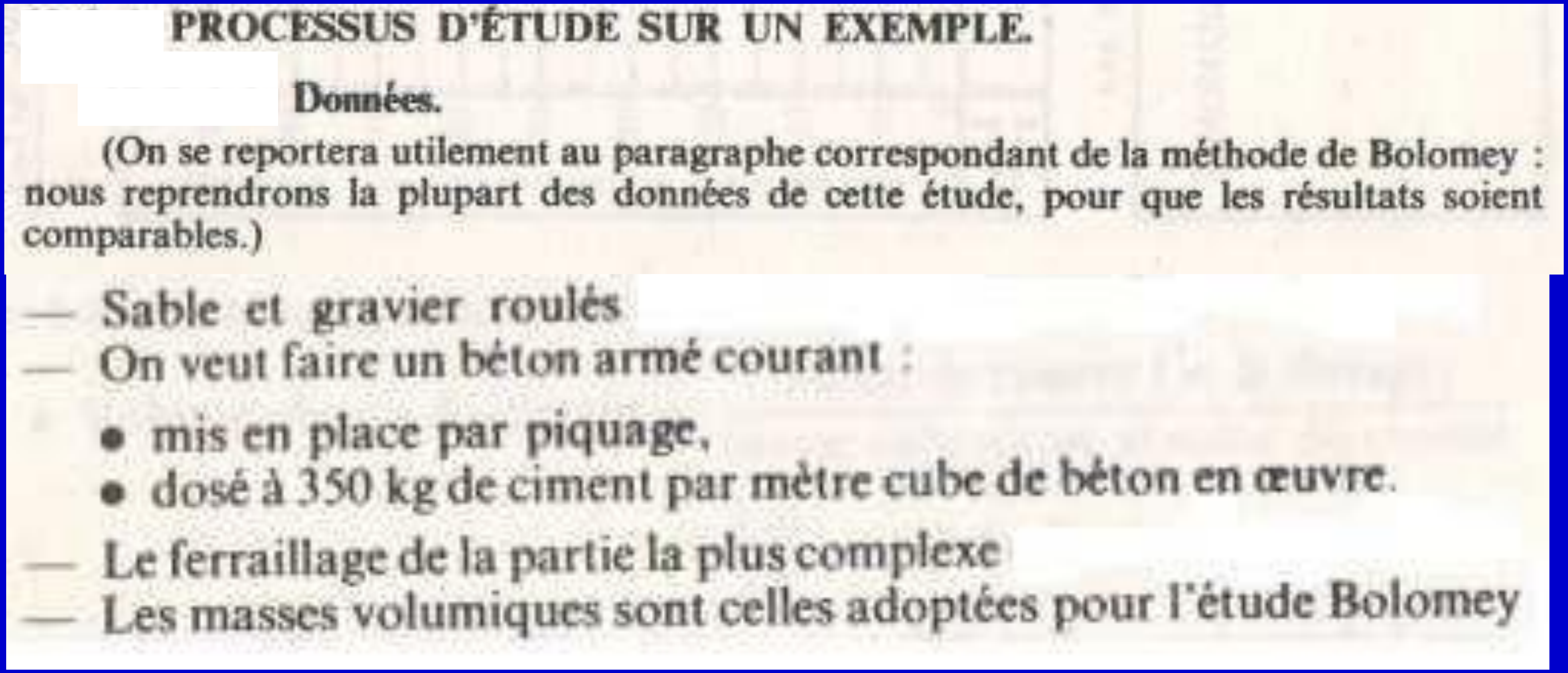
so we have : V cement + V sand V gravel = 1 – W

the absolute volume of cement :

V cement = cement dosage / absolute Mv of cement.

$$C\ (\%) = \frac{V_{cement}}{1000 - W}$$

The volumes of sand, cement and gravel are determined from the grading curve and the Joisel method.The following procedure is similar to that of Bolomey:particle size composition of the mix,composition of a cubic metre of concrete.



PROCESSUS D'ÉTUDE SUR UN EXEMPLE.

Données.

(On se reportera utilement au paragraphe correspondant de la méthode de Bolomey : nous reprendrons la plupart des données de cette étude, pour que les résultats soient comparables.)

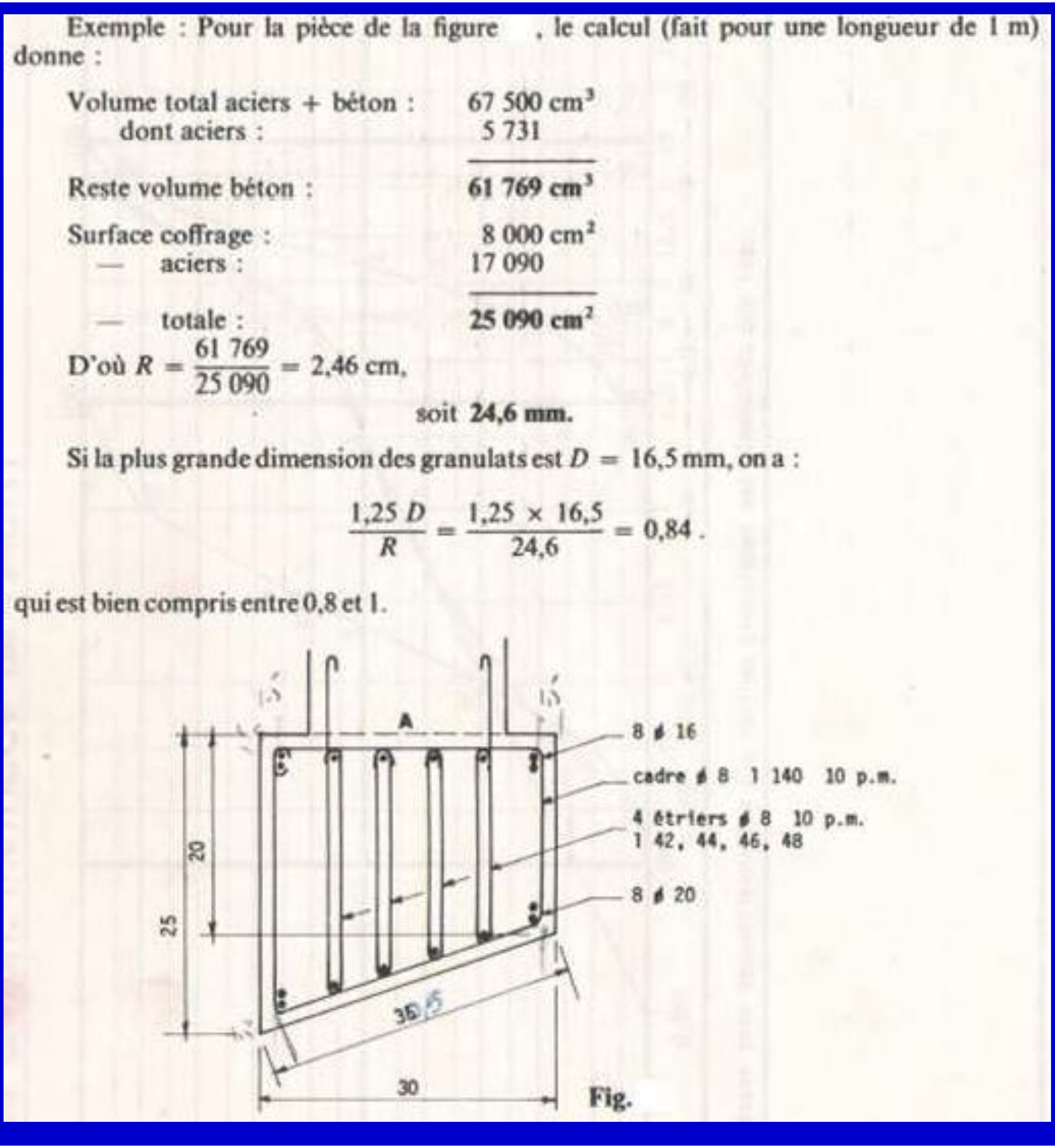
— Sable et gravier roulés

— On veut faire un béton armé courant :

- mis en place par piquage,
- dosé à 350 kg de ciment par mètre cube de béton en œuvre.

— Le ferraillage de la partie la plus complexe

— Les masses volumiques sont celles adoptées pour l'étude Bolomey



Exemple : Pour la pièce de la figure , le calcul (fait pour une longueur de 1 m) donne :

Volume total aciers + béton :	67 500 cm³
dont aciers :	5 731
Reste volume béton :	**61 769 cm³**
Surface coffrage :	8 000 cm²
— aciers :	17 090
— totale :	**25 090 cm²**

D'où $R = \dfrac{61\,769}{25\,090} = 2{,}46$ cm,

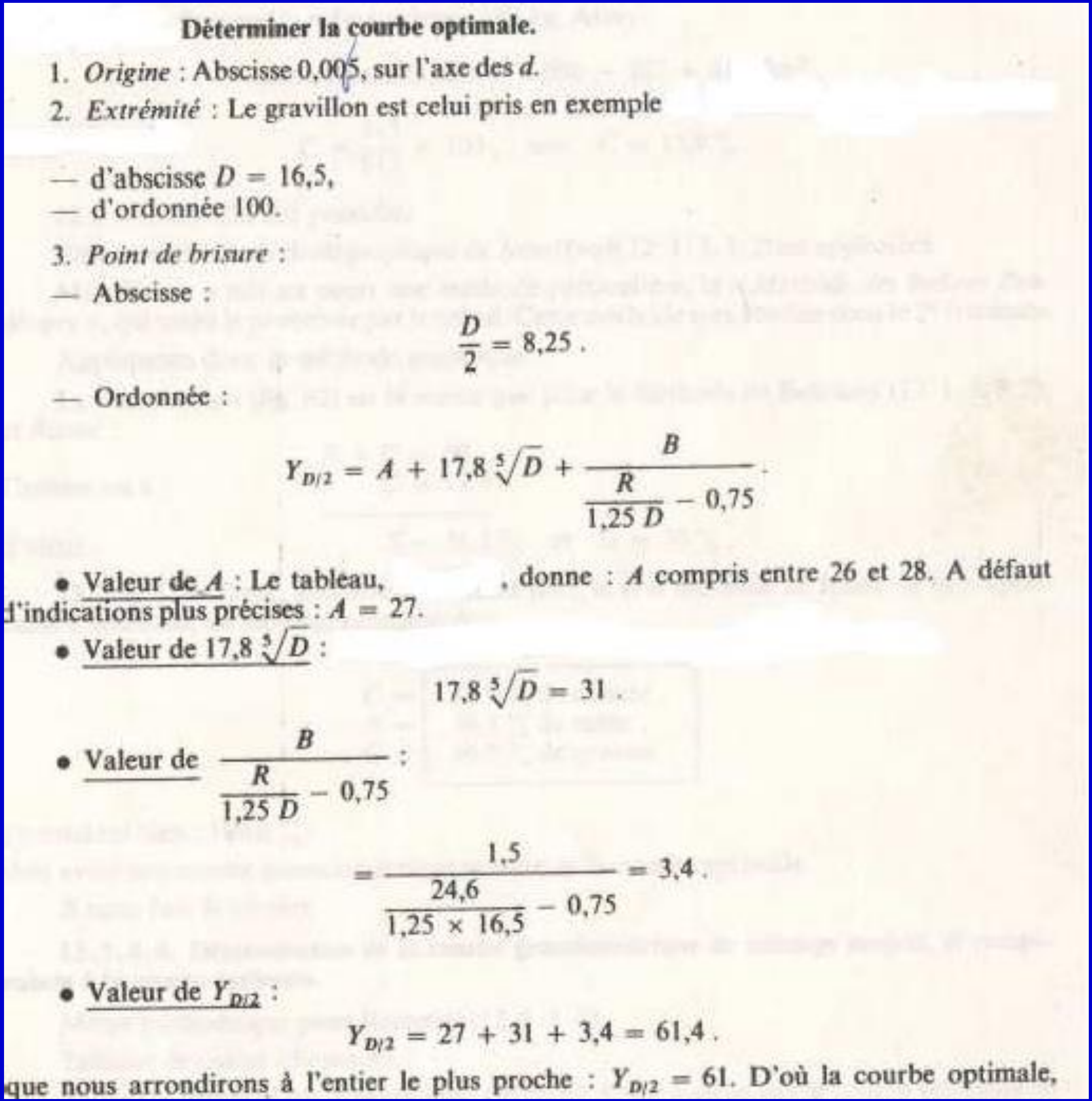
soit **24,6 mm.**

Si la plus grande dimension des granulats est $D = 16{,}5$ mm, on a :

$$\frac{1{,}25\,D}{R} = \frac{1{,}25 \times 16{,}5}{24{,}6} = 0{,}84\,.$$

qui est bien compris entre 0,8 et 1.

Fig.



Déterminer la courbe optimale.

1. *Origine* : Abscisse 0,005, sur l'axe des *d*.
2. *Extrémité* : Le gravillon est celui pris en exemple

— d'abscisse $D = 16{,}5$,
— d'ordonnée 100.

3. *Point de brisure* :

— Abscisse :

$$\frac{D}{2} = 8{,}25 \, .$$

— Ordonnée :

$$Y_{D/2} = A + 17{,}8\sqrt[5]{D} + \frac{B}{\frac{R}{1{,}25\,D} - 0{,}75} \, .$$

- Valeur de A : Le tableau, , donne : A compris entre 26 et 28. A défaut d'indications plus précises : $A = 27$.
- Valeur de $17{,}8\sqrt[5]{D}$:

$$17{,}8\sqrt[5]{D} = 31 \, .$$

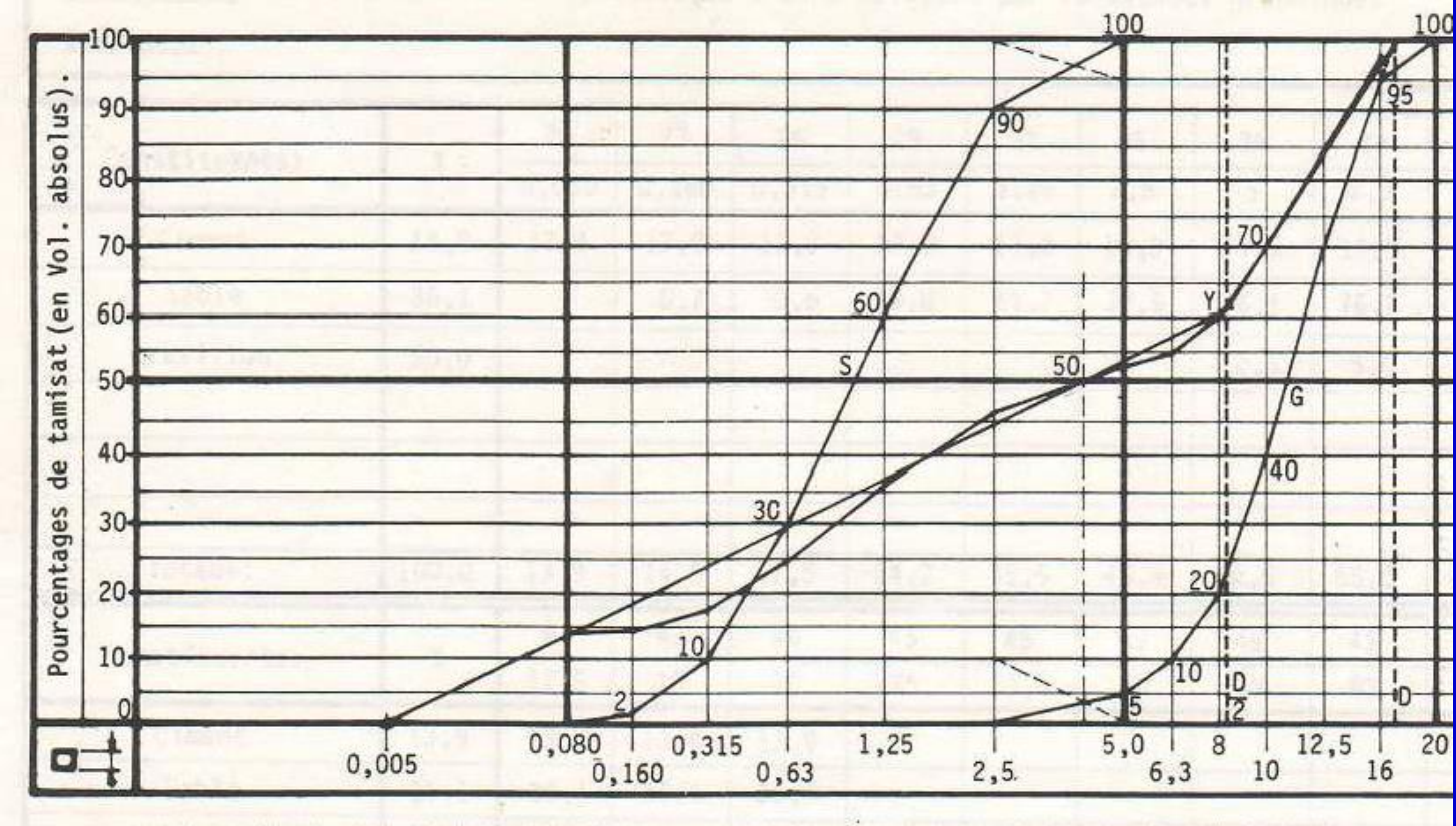
- Valeur de $\frac{B}{\frac{R}{1{,}25\,D} - 0{,}75}$:

$$= \frac{1{,}5}{\frac{24{,}6}{1{,}25 \times 16{,}5} - 0{,}75} = 3{,}4 \, .$$

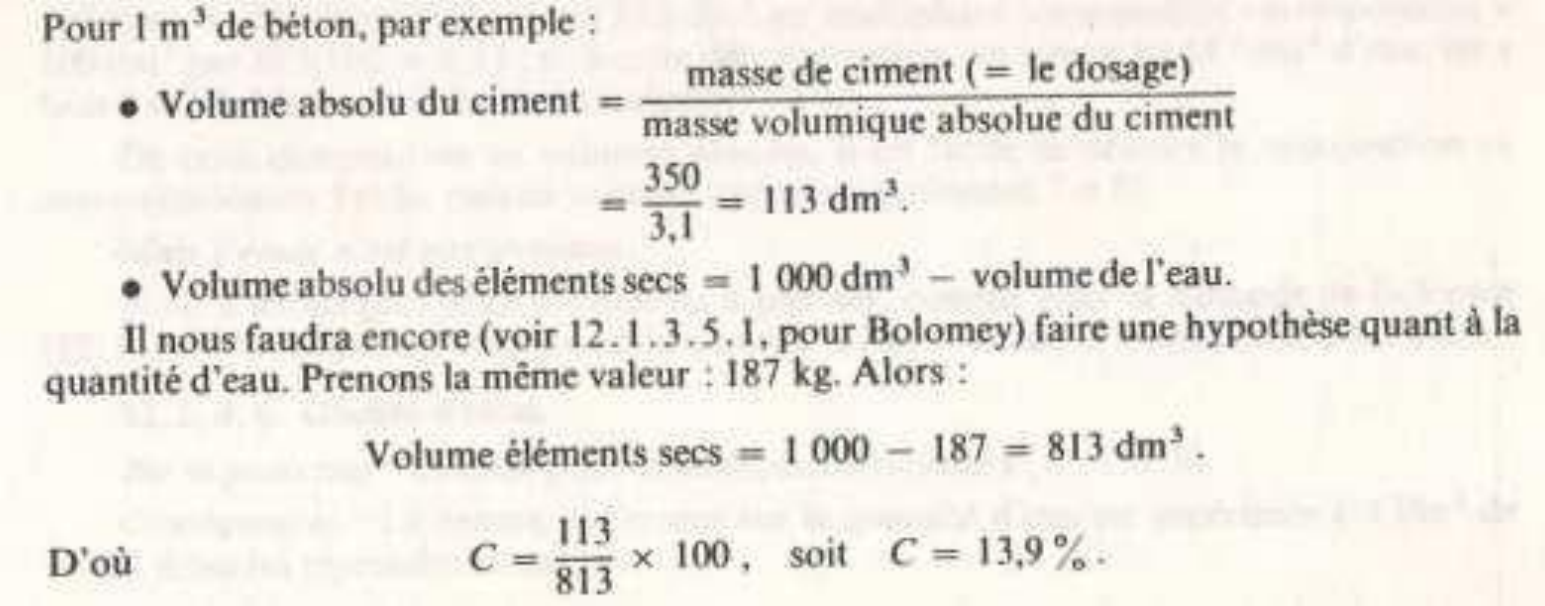
- Valeur de $Y_{D/2}$:

$$Y_{D/2} = 27 + 31 + 3{,}4 = 61{,}4 \, .$$

que nous arrondirons à l'entier le plus proche : $Y_{D/2} = 61$. D'où la courbe optimale,



Les abscisses sont proportionnelles aux racines cinquièmes des dimensions des tamis.



Pour 1 m³ de béton, par exemple :

- Volume absolu du ciment $= \dfrac{\text{masse de ciment (= le dosage)}}{\text{masse volumique absolue du ciment}}$

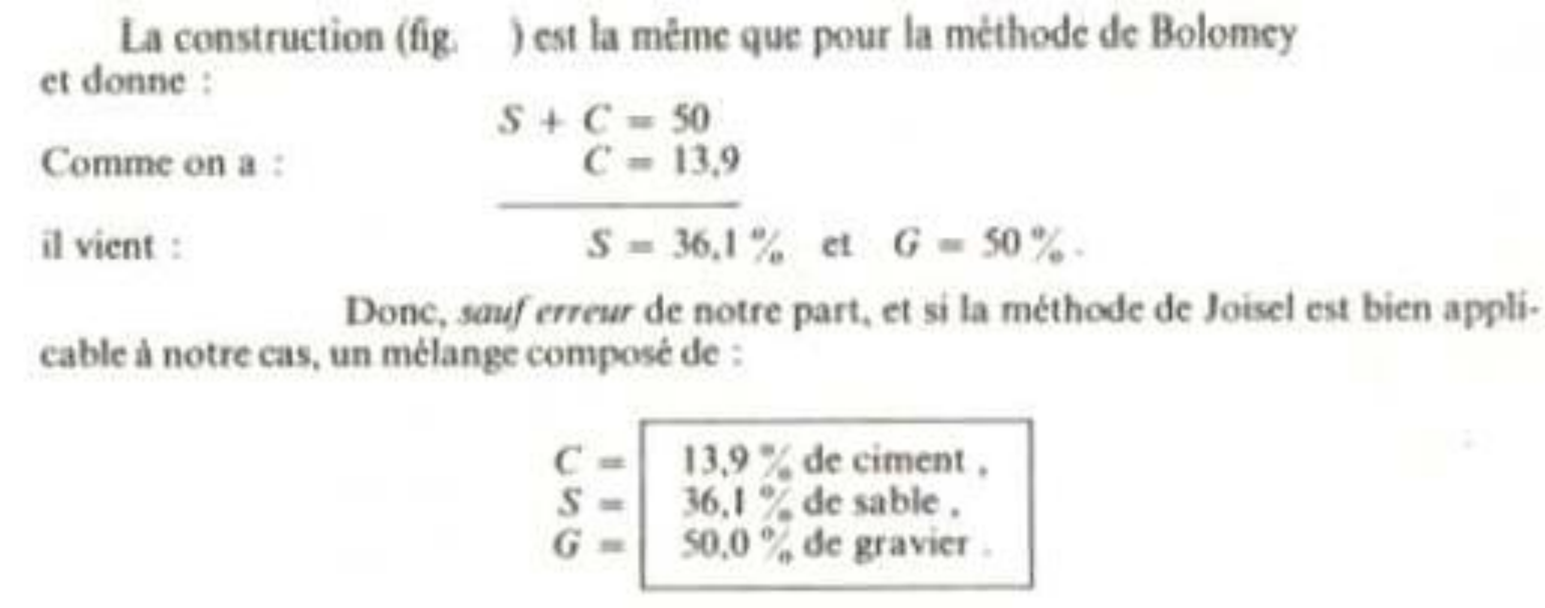
$$= \frac{350}{3{,}1} = 113 \text{ dm}^3.$$

- Volume absolu des éléments secs = 1 000 dm³ − volume de l'eau.

Il nous faudra encore (voir 12.1.3.5.1, pour Bolomey) faire une hypothèse quant à la quantité d'eau. Prenons la même valeur : 187 kg. Alors :

$$\text{Volume éléments secs} = 1\,000 - 187 = 813 \text{ dm}^3 .$$

D'où $C = \dfrac{113}{813} \times 100$, soit $C = 13{,}9\,\%$.



La construction (fig.) est la même que pour la méthode de Bolomey et donne :

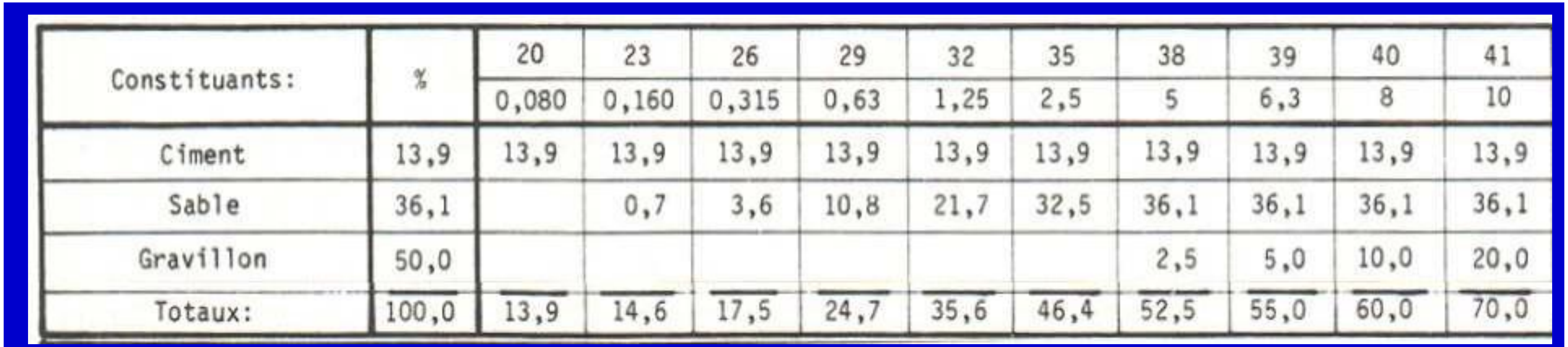
$$S + C = 50$$

Comme on a : $C = 13{,}9$

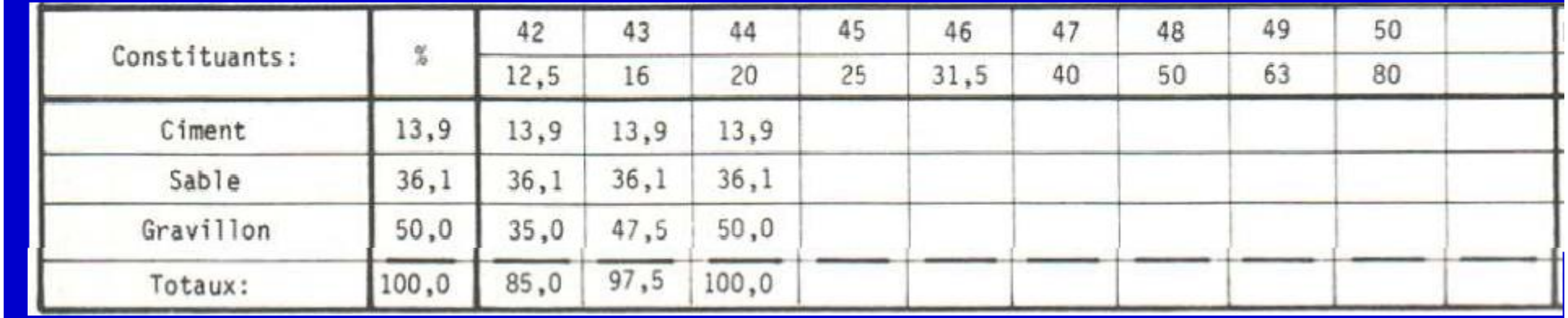
il vient : $S = 36{,}1\,\%$ et $G = 50\,\%$.

Donc, *sauf erreur* de notre part, et si la méthode de Joisel est bien applicable à notre cas, un mélange composé de :

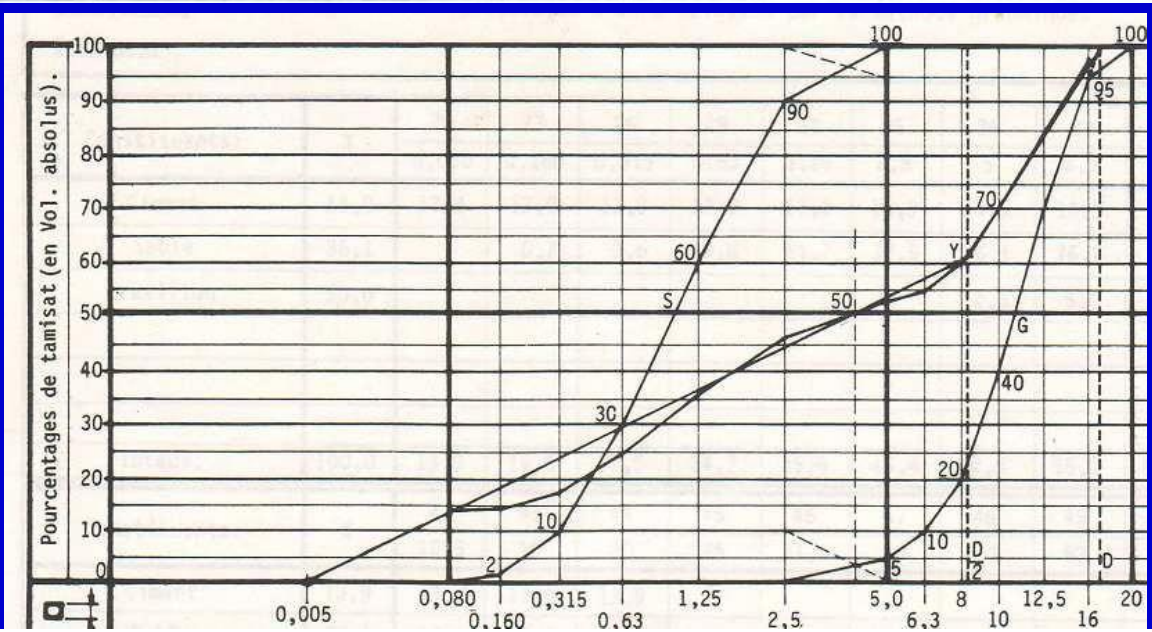
$$\begin{aligned} C &= \\ S &= \\ G &= \end{aligned} \boxed{\begin{aligned} &13{,}9\,\% \text{ de ciment ,} \\ &36{,}1\,\% \text{ de sable ,} \\ &50{,}0\,\% \text{ de gravier .} \end{aligned}}$$

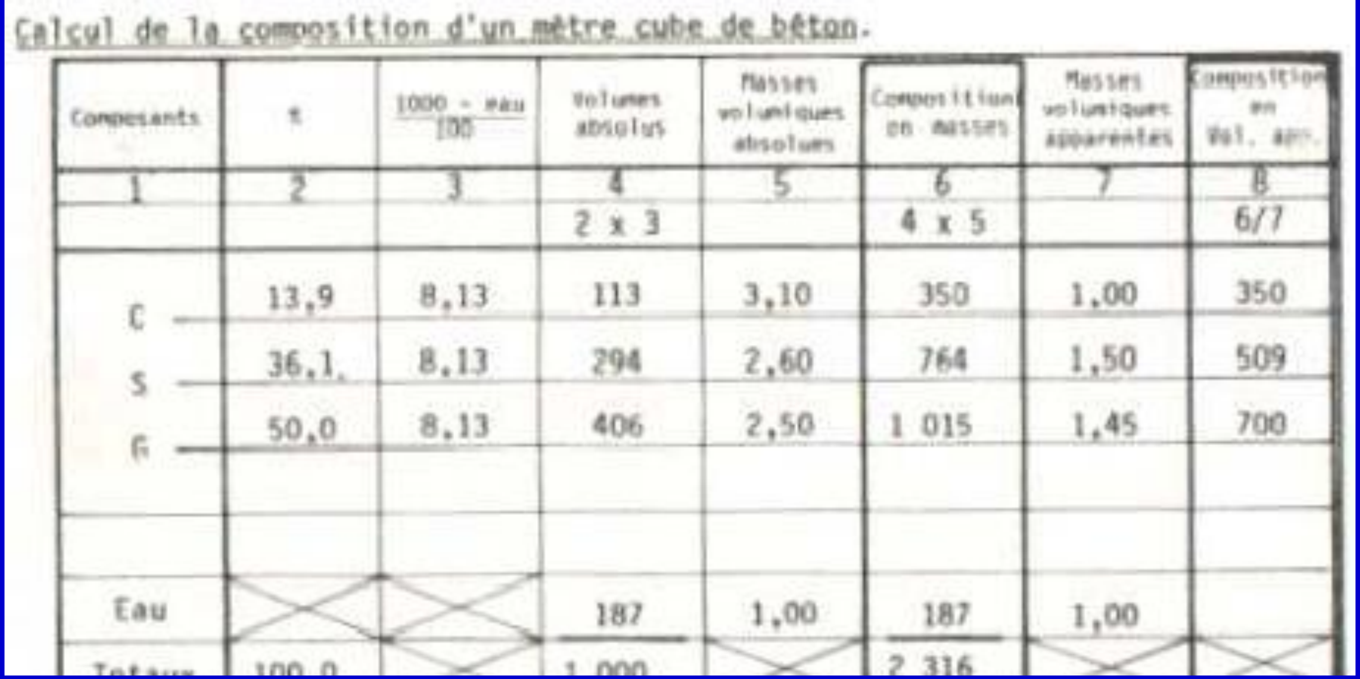


Constituants:	%	20	23	26	29	32	35	38	39	40	41
		0,080	0,160	0,315	0,63	1,25	2,5	5	6,3	8	10
Ciment	13,9	13,9	13,9	13,9	13,9	13,9	13,9	13,9	13,9	13,9	13,9
Sable	36,1		0,7	3,6	10,8	21,7	32,5	36,1	36,1	36,1	36,1
Gravillon	50,0							2,5	5,0	10,0	20,0
Totaux:	100,0	13,9	14,6	17,5	24,7	35,6	46,4	52,5	55,0	60,0	70,0



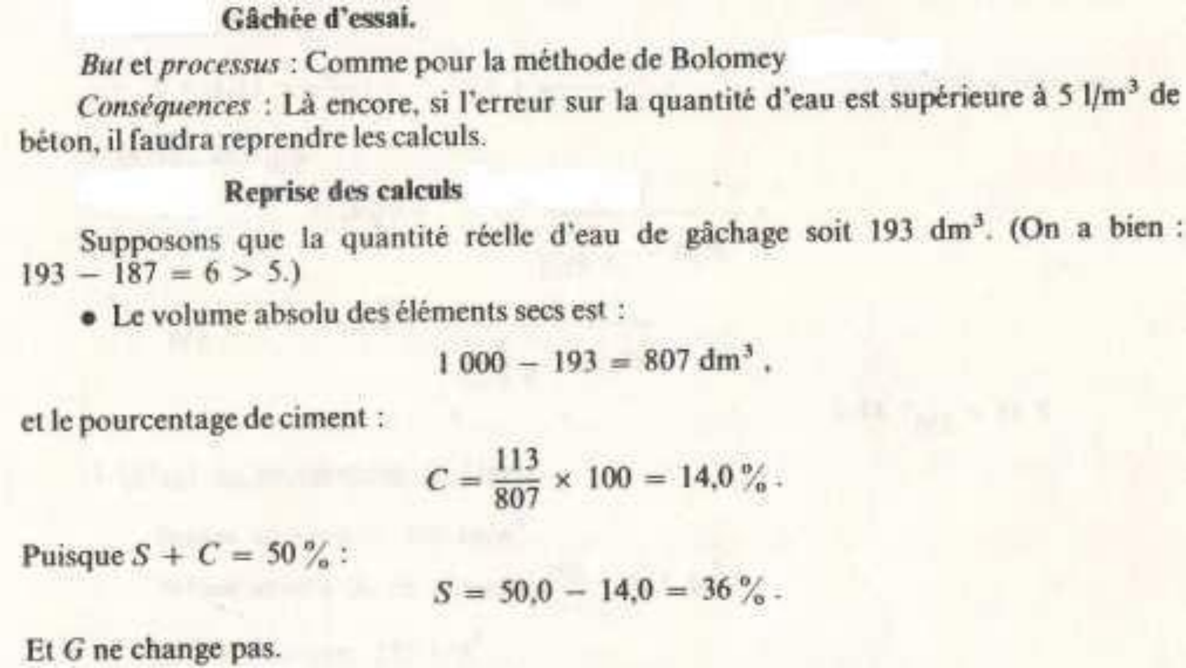
Constituants:	%	42	43	44	45	46	47	48	49	50	
		12,5	16	20	25	31,5	40	50	63	80	
Ciment	13,9	13,9	13,9	13,9							
Sable	36,1	36,1	36,1	36,1							
Gravillon	50,0	35,0	47,5	50,0							
Totaux:	100,0	85,0	97,5	100,0							





Calcul de la composition d'un mètre cube de béton.

Composants	%	$\frac{1000 - eau}{100}$	Volumes absolus	Masses volumiques absolues	Composition en masses	Masses volumiques apparentes	Composition en Vol. app.
1	2	3	4	5	6	7	8
			2 x 3		4 x 5		6/7
C	13,9	8,13	113	3,10	350	1,00	350
S	36,1	8,13	294	2,60	764	1,50	509
G	50,0	8,13	406	2,50	1 015	1,45	700
Eau			187	1,00	187	1,00	
Totaux	100,0		1 000		2 316		



Gâchée d'essai.

But et *processus* : Comme pour la méthode de Bolomey

Conséquences : Là encore, si l'erreur sur la quantité d'eau est supérieure à 5 l/m³ de béton, il faudra reprendre les calculs.

Reprise des calculs

Supposons que la quantité réelle d'eau de gâchage soit 193 dm³. (On a bien : 193 – 187 = 6 > 5.)

- Le volume absolu des éléments secs est :

$$1\,000 - 193 = 807 \text{ dm}^3 .$$

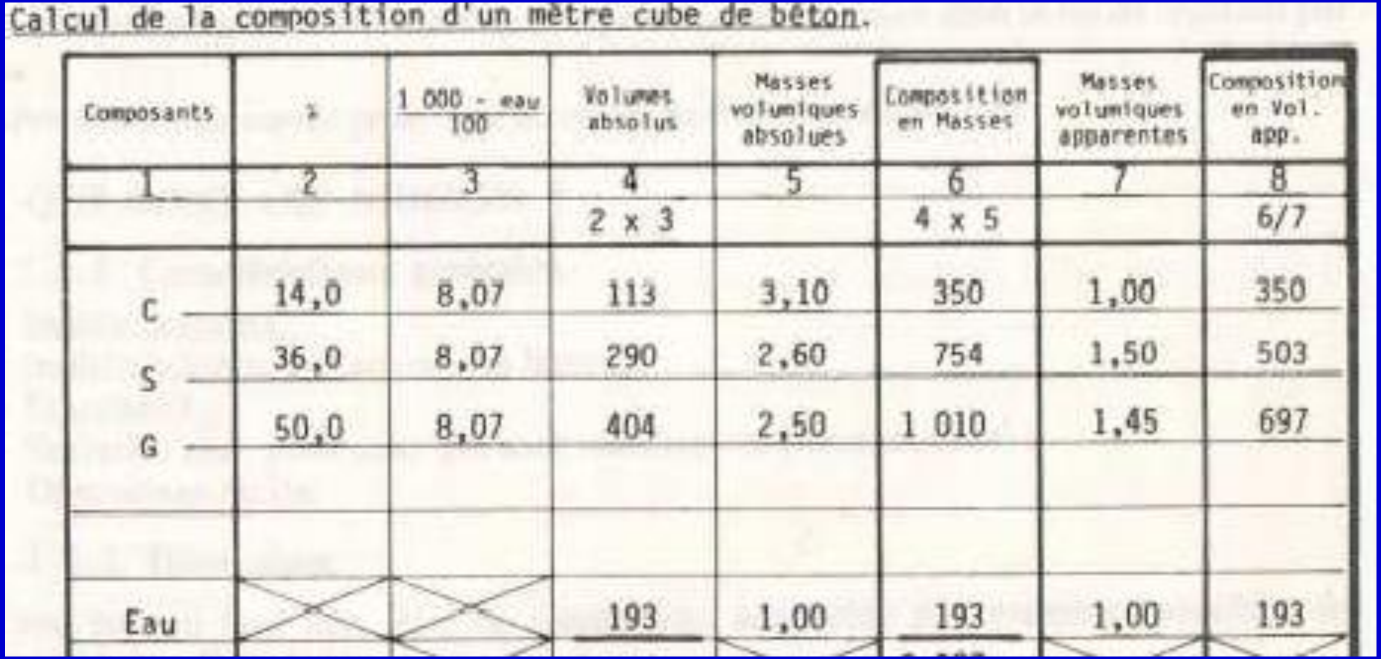
et le pourcentage de ciment :

$$C = \frac{113}{807} \times 100 = 14{,}0\ \% .$$

Puisque $S + C = 50\ \%$:

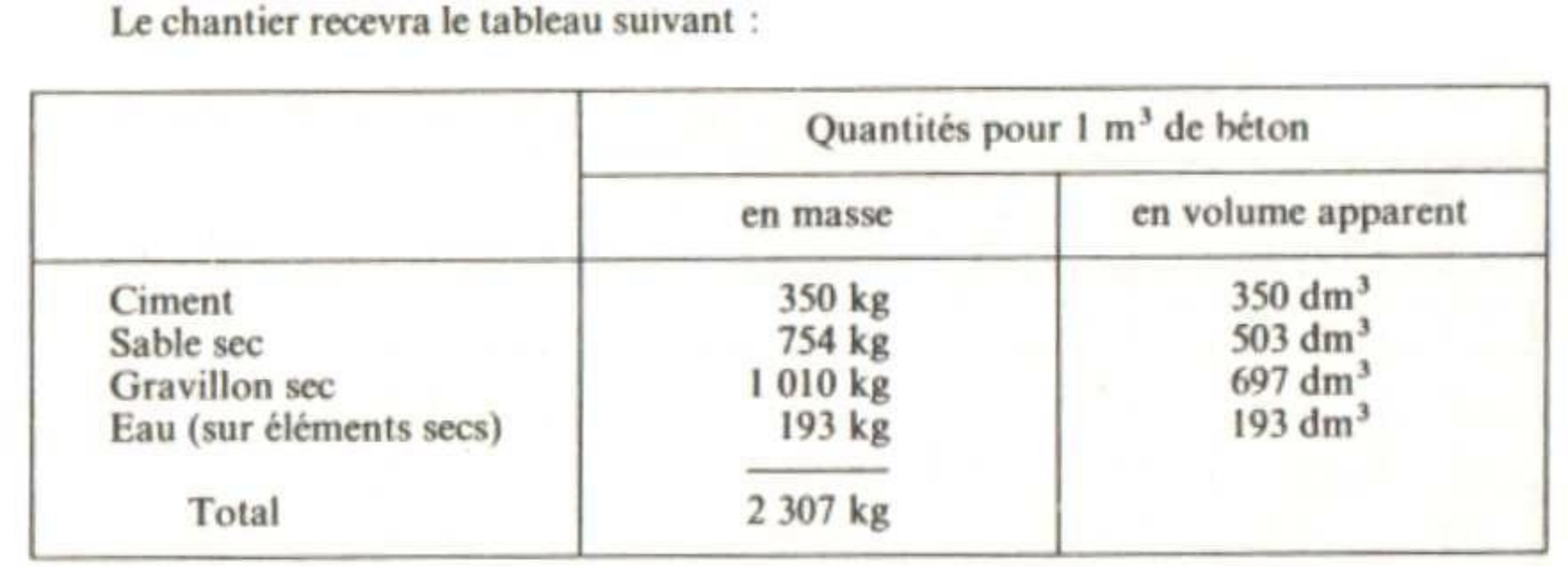
$$S = 50{,}0 - 14{,}0 = 36\ \% .$$

Et G ne change pas.



Calcul de la composition d'un mètre cube de béton.

Composants	%	1 000 - eau / 100	Volumes absolus	Masses volumiques absolues	Composition en Masses	Masses volumiques apparentes	Composition en Vol. app.
1	2	3	4	5	6	7	8
			2 x 3		4 x 5		6/7
C	14,0	8,07	113	3,10	350	1,00	350
S	36,0	8,07	290	2,60	754	1,50	503
G	50,0	8,07	404	2,50	1 010	1,45	697
Eau			193	1,00	193	1,00	193



Le chantier recevra le tableau suivant :

	Quantités pour 1 m³ de béton	
	en masse	en volume apparent
Ciment	350 kg	350 dm³
Sable sec	754 kg	503 dm³
Gravillon sec	1 010 kg	697 dm³
Eau (sur éléments secs)	193 kg	193 dm³
Total	2 307 kg	