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Original citation:
Yousfi, S. , Nouri, L. , Saidani, M. and Hadjab, H. (2014) THE USE OF THE DREUX-GORISSE METHOD IN THE PREPARATION OF CONCRETE MIXES: AN AUTOMATIC APPROACH. Asian Journal of Civil Engineering, volume 15 (1): 79-93

URL: http://ajce.bhrc.ac.ir/tabid/1529/agentType/View/PropertyID/5891/Default.aspx

ASIAN JOURNAL OF CIVIL ENGINEERING (BHRC) VOL. 15, NO. 1 (2014)
PAGES 79-93

THE USE OF THE DREUX-GORISSE METHOD IN THE PREPARATION OF CONCRETE MIXES: AN AUTOMATIC APPROACH

S. Yousfi[1], L. Nouri[1], M. Saidani[*2] and H. Hadjab[3]
[1]University of Boumerdes, Faculty of Engineering, Algeria.
[2]Coventry University, Faculty of Engineering and Computing, Priory Street, Coventry CV1 5FB, UK.
[3]University of Science and Technology Houari Boumediene, Faculty of Civil Engineering, BP 32 Bab Ezzouar, El Alia, Algiers, Algeria.

Received: 15 December 2012; **Accepted:** 10 April 2013

ABSTRACT

Following a comparative study of a number of representative methods for the preparation of a concrete mix, the present paper presents the results one of such methods, namely that of Dreux-Gorisse. This method combines a graphical approach with an analytical one, alongside the use of established correction tables. This study therefore proposes to present the various stages necessary for preparation of a concrete mix using the Dreux-Gorisse method in an automatic way. The purpose of this automation is to enable the preparation of a variety of mixes, taking into account the presence of several parameters. This approach allows obtaining mixes in a comprehensive manner, which eventually can lead to a comparison with other methods for the preparation of concrete mixes.

Keywords: Concrete mix; dreux-gorisse; automation; strength; deformability; workability.

1. INTRODUCTION

In old times people used to build with stone, cooked bricks, earth blended in the straw, wood as well as with other more or less known materials. But almost one and a half century ago, a new era started with the invention of concrete. Since, this material became the object of numerous studies, always with the intention of improving its strength, ductility, workability and economy. All research carried out pointed out to the fact that concrete introduced vast technical and economic possibilities in comparison with other materials, such as stone, wood

[*]E-mail address of the corresponding author: cbx086@coventry.ac.uk (M. Saidani)

or even steel.

In what follows, definitions of some of the main properties of this material are given, according to different authors, e.g. Refs. [1-2]. There are a number of definitions, but they to join each other.

Concrete is a mixture of very different constituents: liquid (water), active powder (sociable) and solid inert (aggregates: big wholesale trade sands down: gravels or crushed stones). This mixture is dosed in order to acquire at the time of the implementation a proper consistency, and after hardening requested qualities, according to which the desired concrete composition is obtained [1-2]. These qualities are:

- strength (principally the compressive strength);
- deformability;
- workability at the time of the implementation.

As there are several methods of concrete mixing, the authors attempted to cover the most popular ones with the aim of broadening the investigation. Methods initially covered include those reported in references [3-7]. The authors made the decision to only concentrate on the method of Dreux-Gorisse, as it was found to be the most user friendly.

The study of the composition of a concrete mix consists in defining the optimum mixture of the aggregates as well as the proportions in cement and water, and this with the intention of accomplishing the desired concrete qualities. In talking about the qualities of concrete, it is worth mentioning the definition given by Gorisse-Dreux [6-7]:

“The study of a concrete mix consists almost always in searching jointly two essential qualities, which are mutually linked and on whom they depend. These two qualities are: strength and workability”. The chosen Dreux-Gorisse composition methods lead to volumic or weighted contents of binders and granulates. In the present work, the weighted contents have been used. The passage from one content to another may be carried out by the knowledge of apparent density granulates used in bulk.

Methods presented by Gorisse-Dreux are said to be in «continuous granularity» or in « discontinuous granularity ».When concrete granulometric analysis allows the drawing of an uninterrupted curve that starts from the smallest cement grain to the biggest gravel grain, going through all the intermediate grains sizes, the composition is said to be “continuous granularity”. In the other hand, when the granular curve shows a stage where there is a lack of intermediate elements, the composition is said to be “discontinuous granularity”. Both cases present advantages and disadvantages and depend on the size of the granulates which constitute the composition. So, the continuous granularity allows acquiring more plastic concretes with a good workability. Conversely, the discontinuous granularity gives concretes with a maximum of large size granulates (gravels) and a minimum of small size granulates (sand), leading in general to a better compressive strength in respect to the continuous granularity but this result is reached to the detriment of the workability that is one of the two main concrete qualities. The concrete composition methods, in their diversities, are only approaching the true compositions, since these are always corrected in situ.

Every method for obtaining a concrete mix has its hypotheses, its advantages and its disadvantages. There are empirical methods, such as ACI [8], Dreux-Gorisse [6-7], experimental methods, BARON-LESAGE [9], and theoretical methods, Auchatraire [10].

These formulations are quite lengthy and laborious to use.

In the present study, the authors developed algorithms and a computer program with the intention of arriving at the required optimum concrete mix as quickly as possible. These programs also allow the possibility of a multitude of formulations in an automated and a rather short period of time.

The choice in presenting the data and results in a table form greatly simplifies the operator task. If one or several characteristics of a concrete mix are changed (eg. proportion of cement, consistency, strength etc.), the new mix is worked out automatically and at ease.

The authors worked out the programming of several methods, but the most arduous proved to be that of Dreux-Gorisse, because it calls upon other programs, among others, that of the particle size curve of reference.

2. DREUX-GORISSE METHOD

It is a very practical and simplified method, consisting of the following stages:

2.1 Basic data.

2.1.1 Nature of structure

The knowledge of structure nature is necessary. It would be necessary to know if structure is massive or high, if it is thin or thick, or if it is heavily reinforced or not. The position of the reinforcement in the most reinforced zones must be known as well.

2.1.2 Required strength

In general, the compressive strength at 28 days is sought. This latter is greater than the nominal strength σ’m .If an overage variation coefficient of 20 % is accepted, it will be possible to adopt the approximate rule for the compressive strength: $\sigma'_{28} = \sigma'_{m} + 15\%$.

2.1.3 Required consistency or workability

This property is defined, in general, by the required plasticity measured using the well established Abrams cone test. The consistency depends on the structure type, the concreting difficulty and on the clamping means as it is shown in Table 1.

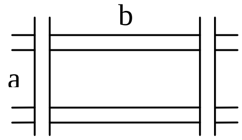
Table 1: Relationship between consistency, concrete clamping, Abrams cone collapse and number of impacts of the C.E.S test

Consistency	**Clamping**	**Collapse A in cm**	**Number of impacts N C.E.S test.**
Very firm concrete	Powerful vibration	0 to 2	>60
Firm concrete	Good vibration	3 to 5	30 to 50
Plastic concrete	Common vibration	6 to 9	15 to 25
Soft concrete	Stitching	10 to 13	10 to 15
Liquid concrete	Light stitching	≥14	<10

2.2 Aggregates maximum dimension

The determination of the aggregates maximum dimension D (Dmax) depends on the characteristics of the structure part to be concreted and the environment aggressiveness as is shown in Table 2.

Table 2: Maximum aggregates diameter according to the parts to be concreted characteristics

characteristics of the structure part to be concreted		**Sieve diameter D**
e_h : reinforcement horizontal spacing		$\leq e_h/1.5$
e_v : reinforcement vertical spacing		$\leq e_v$
c: spacing between reinforcement and formwork	very aggressive environment $c \geq 4$cm	<c
	slightly aggressive environment: $c \geq 3$cm	
	lowly aggressive environment: $c \geq 2$cm	
	not aggressive environment: $c \geq 1$cm	
r: reinforcement radius	rolled aggregates	≤ 1.4 r
	crushed aggregates	≤ 1.2 r
	$ab/r = 2(a+b)$	
h= height or minima thickness		$\leq h_m/5$

2.3 Cement content

The cement content differs from the aggregates content. The cement/water ratio (C/W) is approximately evaluated using the overage strength σ'_{28} and the required plasticity through the following formula.

$$\sigma'_{28} = G\,\sigma'_c(C/E - 0.5) \quad (1)$$

Where σ'_{28}: is the required overage compressive strength at 28 days (expressed in bars).
σ'_c: is the true cement class at 28 days (expressed in bars)

C: is then cement content (expressed in kg / m^3)
W: is the total water content in dry materials (expressed in litre for a cubic metre)
G: is the granular coefficient with values are given in table 3 according to the aggregates quality and dimensions.

Table 3: Approximate values of the granular coefficient G

aggregates quality	Aggregates dimension D		
	fine: $D \leq 16$ mm	medium: $25 \leq D \leq 40$mm	coarse: $D \geq 63$ mm
very good	0.55	0.6	0.65
good, common	0.45	0.5	0.55
fairly good	0.35	0.4	0.45

Knowing the report C/W ratio and the desired workability, considered as a basic data, the cement content can be approximately evaluated by using the chart (Dreux, 1981) depicted in Figure 1.

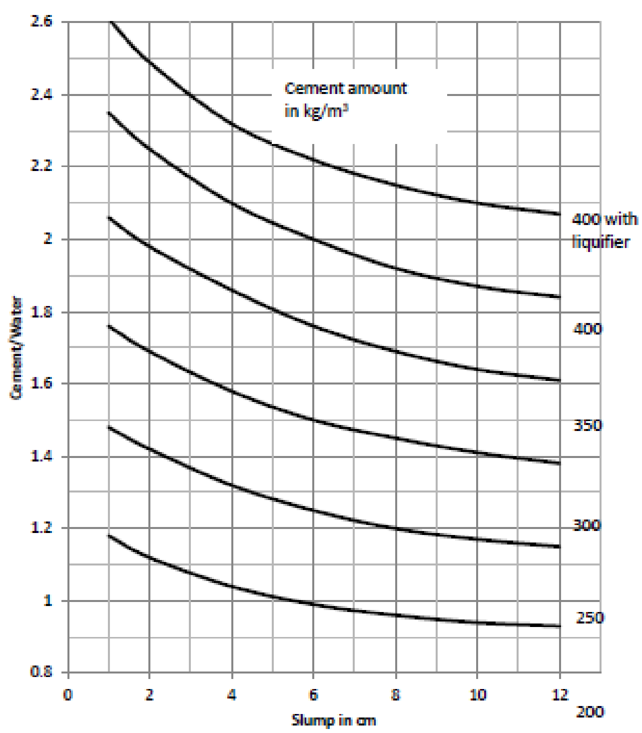


Figure 1. Chart giving approximate cement content to use in respect to the required C/W ratio and the workability (cone collapse). [6]

2.4 Water content

The choice of the cement content C and the C/W ratio values lead obviously to water content which value is only approximate. This latter will be adjusted subsequently through plasticity and workability tests.

W = C / (C/W).

2.5. Aggregates

2.5.1 Aggregates quality

Gravels must be of good mineralogical quality, hard and very clean. Sand must also be clean, its required fineness modulus value must range from 2.2 to 2.8 and its corresponding granulometric curve must be compared with the optimum distribution as depicted in Figure 2.

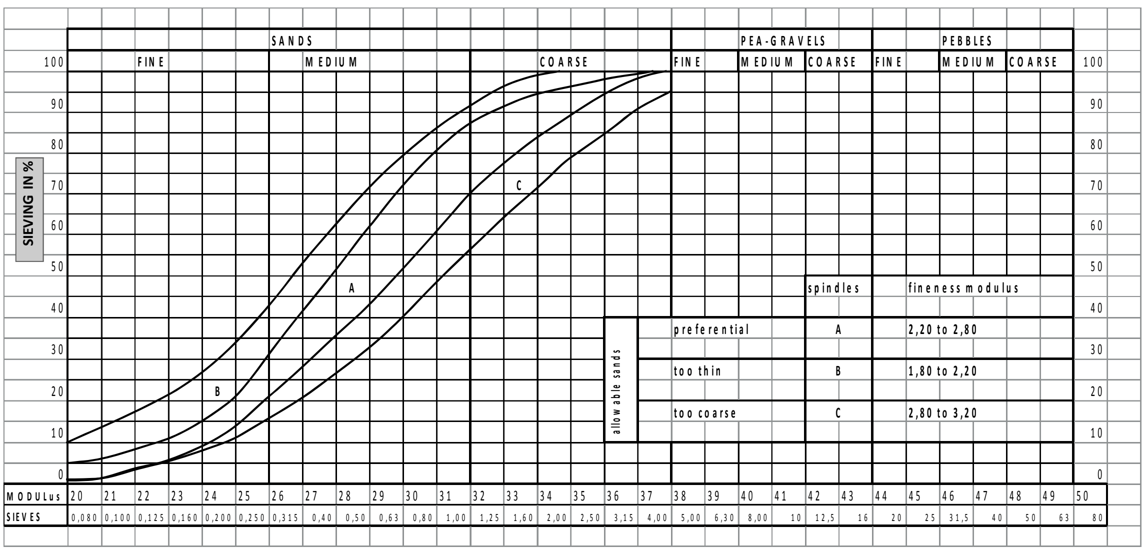


Figure 2. Proposed distribution curves for concrete sands granularity [6].

2.5.2. Granular reference curve and aggregates content

On a granulometric analysis graph, a reference composition AOB is drawn. The point B (at 100%) corresponds to the dimension D of the greatest aggregate. The breaking point A is defined by the following coordinates in abscissa (from the dimension D sieve):

If D 20 mm, the abscissa is D/2

If D>20 mm, the abscissa is located in the middle of the "gravel segment" limited by modulus 38 (corresponding to 5mm) and the corresponding modulus to D, at:

$$Y=50-\sqrt{D}+K \tag{2}$$

Where K is a corrective term which depends on the cement content, the clamping effectiveness, the rolled or crushed aggregates shape (the sand influence is especially preponderant) and also on the sand fineness modulus.

The granular reference curve OAB must be drawn on the same graph as the granulometric curves of the components aggregates. Then, the dividing lines between each aggregates type are drawn. This is carried out by joining the point at 95 % of the granular curve of the first aggregates type to the point at 5 % of the granular curve of the following aggregates type and so on.

Consequently, the percentage in net volume of each of the aggregates g1, g2, g3 etc... is read on the reference curve at the dividing lines crossing point. As C is the cement content, the cement grains net volume is:

$$c= C/ \rho_c \qquad (3)$$

where c is the cement grains specific mass equals to 3.1 (which is the overage value habitually accepted). The net volume of all the aggregates is:

$$V=1000\gamma -c \qquad (4)$$

where is the compactness coefficient.

The net volumes of each of the aggregates are then:

$$v_1 \geq g_1V, v_2 \geq g_2V, v_3 \geq g_3V \qquad (5)$$

If the specific masses of each of this aggregate are respectively 1, 2, 3, the masses of each of them will be:

$$p_1=v_1 \varpi_{1}, p_2=v_2 \varpi_{2}, p_3=v_3 \varpi_{3} \qquad (6)$$

and the total aggregates mass will be:

$$G=p_1+p_2+p_3 \qquad (7)$$

2.7. Compactness Coefficient

The compactness coefficient is calculated as the absolute volumes of the solid materials VM divided by the total volume of implemented fresh concrete i.e. one metre cubed. That is:

$$\gamma =VM \text{ (in litres)}/1000 \qquad (8)$$

$$VM=Vg+Vs+Vc \qquad (9)$$

γ is given according to the consistency, the clamping and the dimension D [6].

As the concrete composition methods are widely dependent on empirical results, their programming is often reduced to predefined tables taking into account implementation parameters.

It seems wise to avoid a sequential treatment, which would be only weighting down the program analysis without bringing any real effective benefit, to the advantage of a pseudo-parallel treatment in a worksheet form where data and results are gathered in a same simpler and more intuitive table to be exploited than a values list even structured.

This Dreux-Gorisse method is not easy to program because it requires a prior treatment from the granulometric curves of the concrete different components. This prior treatment consists in preparing the characteristic points which are necessary for the determination of the reference curve. The method combines a graphical and an analytical treatment associated with a consultation of correction table. Figures 3 to 4 form a series of flowcharts that must be treated in parallel.

3. FLOW CHART

3.1 Reference curve parameters preparation

GRANULOMETRIC CURVE						
Strainer	Sieve	modulus	sand n°1	sand n°2	gravel n°1	gravel n°2
0.100	0.080	20				
0.125	0.100	21				
…	…	…				
…	…	…				
…	…	…				
80.000	63.000	49				
100.000	80.000	50				

fineness modulus required	sand n°1 %	sand n°2 %
sand n°1 fineness modulus	gravel n°1 greater diameter	
sand n°2 fineness modulus	gravel n°2 greater diameter	

	modulus =5%	modulus =95%	modulus ≥5%	corresponding %	modulus ≤95%	corresponding %
final sand						
sand n°1						
sand n°2						
gravel n°1						
gravel n°2						
			modulus ≤5%	corresponding %	modulus ≥95%	corresponding %
final sand						
sand n°1						
sand n°2						
gravel n°1						
gravel n°2						

Figure 3. Flowchart for the determination of the reference granulometric curve parameters.

3.2 Determination of cement and water content according to Dreux-Gorisse [6]

Density	real density	apparent density	sand fineness modulus			
gravel n°1						without air entraining: 1
gravel n°2			compressive strength (Mpa)			
Sand			consistency	extremely dry: 2	very rigid: 4	rigid: 6
cement				rigid-plastic: 8	plastic: 10	fluid: 12
cement class		aggregates quality		excellent: 1	common: 2	fairly good: 3
aggregates shape		Sand				
rolled: 1	crushed: 2	gravels				
vibration		Stitching: 0	weak: 1	normal: 2	powerful: 3	
maximum diameter		modulus: max				

	granular coefficient G					C/W ratio working out	
aggregates quality	aggregates Dmax (mm)					Dmax=	
	$D\le16$	$16<D<25$	$25\le D\le40$	$40<D<63$	$D\ge63$	aggregates quality	
1	0.55	0.58	0.60	0.63	0.65	G	
2	0.45	0.48	0.50	0.53	0.55	Cement class	
3	0.35	0.38	0.40	0.43	0.45	C/W =	
theoretical cement content:						-	
real cement content:						400.00	+ plasticizer

cement content						
	consistency (Abrams cone settlement in mm)					
C/W ratio	2	4	6	8	10	12
1.0	179.42	188.15	200.00	208.20	213.04	218.18
1.2	213.46	226.89	239.37	250.00	256.25	262.61
1.4	247.50	265.63	279.92	290.24	298.33	346.25
1.6	283.93	304.23	318.21	332.08	338.21	392.87
1.8	317.48	339.44	354.69	369.09	382.34	435.00
2.0	375.92	378.02	400.00	414.78	426.27	476.67
2.2	389.62	421.93	443.81	459.55	468.01	-
2.4	430.67	465.35	488.5	-	-	-
2.6	451.19	-	-	-	-	-

water content correction	
maximum diameter	correction in %
5	15
10	9
16	4
25	0
40	-4
63	-8
100	-12

water	Cement

Density	real density	apparent density	sand fineness modulus			
gravel n°1						without air entraining: 1
gravel n°2			compressive strength (Mpa)			
Sand			consistency	extremely dry: 2	very rigid: 4	rigid: 6
cement				rigid-plastic: 8	plastic: 10	fluid: 12
cement class		aggregates quality		excellent: 1	common: 2	fairly good: 3
aggregates shape		Sand				
rolled: 1	crushed: 2	Gravels				
vibration		Stitching: 0	weak: 1	normal: 2	powerful: 3	
maximum diameter		modulus: max				

Sand and gravels content according to Dreux-Gorisse [6]

corrective term K in the formula: Y=50- $\sqrt{D}$ + K						
vibration	Weak		Normal		Powerful	
Granular shape	rolled	crushed	rolled	crushed	rolled	crushed
200	8	10	6	8	4	6
250	6	8	4	6	2	4
300	4	6	2	4	0	2
350	2	4	0	2	-2	0
400	0	2	-2	0	-4	-2
400+plasticizer	-2	0	-4	-2	-6	-4
cement content			correct term. Ks=6Mf-15			
reference curve breaking point coordinates:			X=		Y=	

% sand
% gravel n°1
% gravel n°2

compactness Gamma coefficient									
consistency	clamping	diameter in mm							
		5	10	12.5	20	31.5	50	80	100
soft ST>12	Stitching	0.750	0.780	0.795	0.805	0.810	0.815	0.820	0.825
	weak vibration	0.755	0.785	0.800	0.810	0.815	0.820	0.825	0.830
	normal vibration	0.760	0.790	0.805	0.815	0.820	0.825	0.830	0.835
plastic 2<ST<12	Stitching	0.760	0.790	0.805	0.815	0.820	0.825	0.830	0.835
	weak vibration	0.765	0.795	0.810	0.820	0.825	0.830	0.835	0.840
	normal vibration	0.770	0.800	0.815	0.825	0.830	0.835	0.840	0.845
	powerful vibration	0.775	0.805	0.820	0.830	0.835	0.840	0.845	0.850
Firm ST<2	weak vibration	0.775	0.805	0.820	0.830	0.835	0.840	0.845	0.850
	normal vibration	0.780	0.810	0.825	0.835	0.840	0.845	0.850	0.855
	powerful vibration	0.785	0.815	0.830	0.840	0.845	0.850	0.855	0.860

Real cement content :

components absolute volume	
Cement	
V=	
Sand	
gravel n°1	
gravel n°2	

sand	gravel n°1	gravel n°2

Figure 4. Dreux-Gorisse method flowchart

4. PROGRAM USAGE

For the program user, it is sufficient just to fill the worksheet boxes corresponding to the materials used. To make the program working, the granulometric curve worksheet must be fully and correctly completed. The program user must also indicate the following values:

-sand fineness modulus value

-compressive strength value (in MPa)

-required consistency value

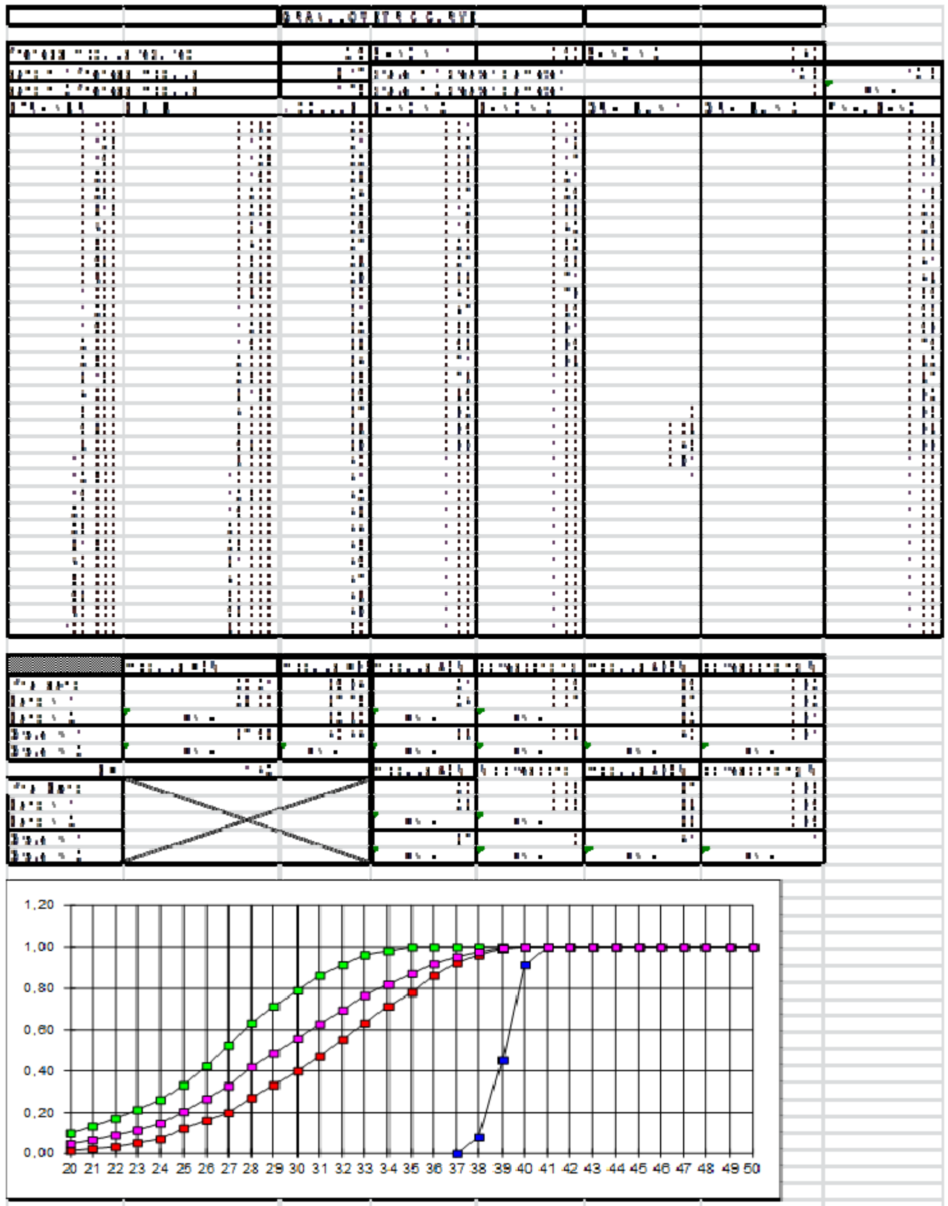
In case where there is no air entraining, the value one '1' must appear in the corresponding worksheet box.

It must be checked that the aggregates and cement apparent and real densities have been indicated. Besides that, information about the following items must be added:

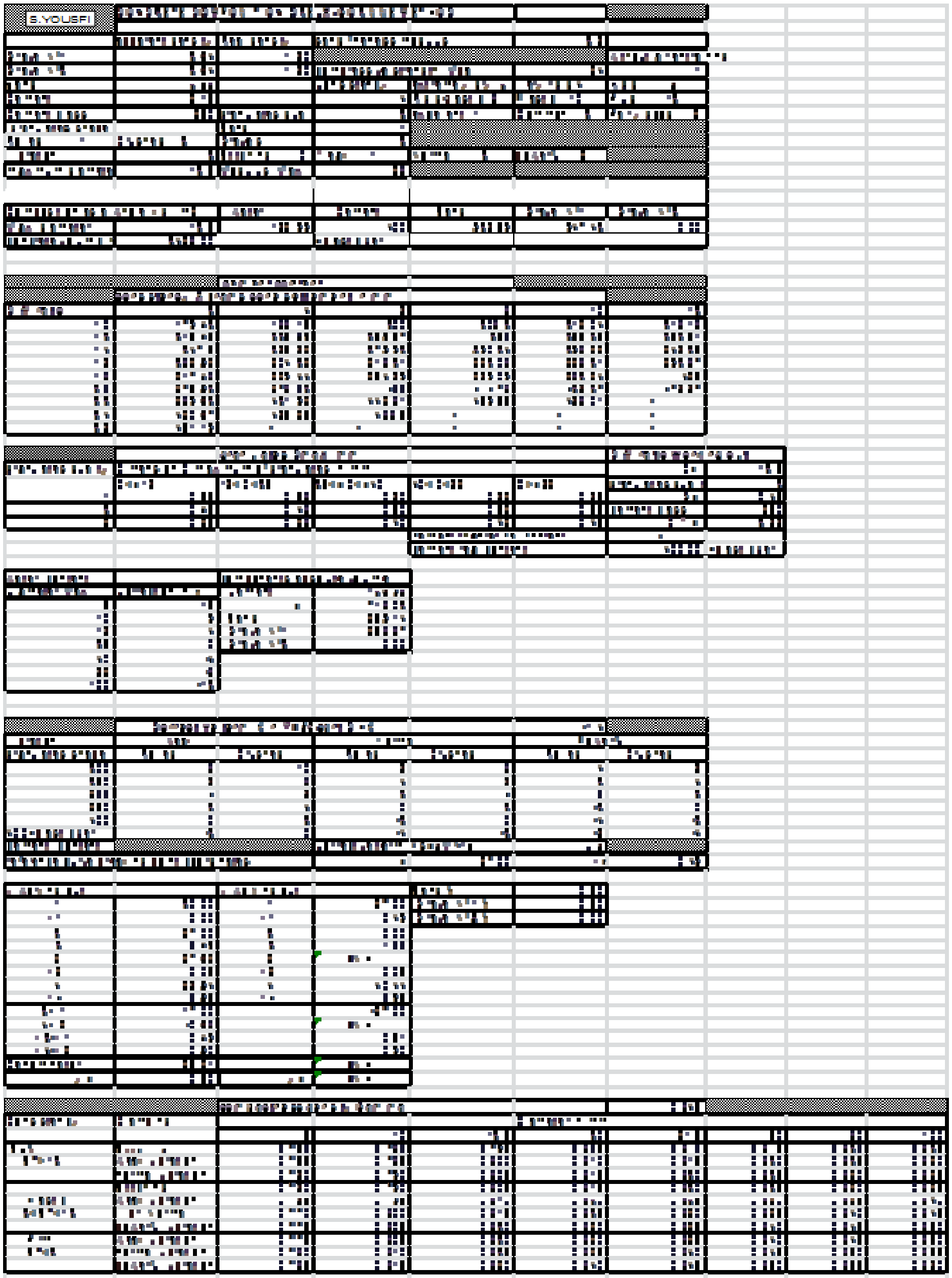
- The cement class: in the present work, as there is a great number of compositions, only cement class 32.5 has been studied.
- The aggregates quality: for practical reason, the aggregates quality has been indexed which allows a qualities numbering leading to an easy data.
- The aggregates shape (rolled or crushed): the values 1 and 2 that correspond respectively to the sand and the gravels are entered in the worksheet boxes.
- The vibrations: the required vibration number is affected to the corresponding worksheet box.
- The program output is given in a table where the obtained results are the different components contents of the required concrete.

5. APPLICATION

In order to illustrate the concrete mixture program elaborated in the present work, data has been introduced in the worksheets (worksheet n°1 and worksheet n°2) joined to this paper. As may be seen, the concrete mixture results investigated appear on the same table as data previously introduced.



Worksheet no.1


S.YOUSFI

Worksheet no.2

6. CONCLUSIONS

The present automatisation of obtaining adequate concrete mix is seen to be effective and user-friendly and very easy to use.

Indeed, in order to obtain the requested mixture, it is sufficient to mention the required characteristics (such as: fineness modulus, consistency, strength, etc.). This method allows achieving a great number of concrete mixtures, thus leading to a global insight of their variation. Moreover, the acquired programming results can be used as concrete mix design charts.

In the present work, the cement Portland artificial 32.5 classes has been used. Nevertheless, other cements or cement classes can be used as data with no difficulties.

One of the aims of the present study is to simplify the task of those who are interested in concrete formulations according to Dreux-Gorisse method.

Finally, it is hoped that the proposed automatization will allow a saving in the time taken in the determination of the concrete mixture.

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