

Task T3.2
Contribution for a Full Prefabrication Approach of
Masonry Reinforced Shells

Joaquim O. Barros, Paulo B. Lourenço,
Juliana T. Oliveira, Everaldo Bonaldo

Report 03-DEC/E-05

*The present research has been carried out under
contract GROW-1999-70420 “ISO-BRICK” from the European Commission*

Date: February 2003

No. of pages: 15

Keywords: Reinforced masonry shells, Prefabrication



Escola de
Engenharia



Departamento de
Engenharia Civil



Universidade
do Minho



Table of Contents

1. General Aspects	1
2. Description of the Construction Process	4
3. Shell Appearance	7
4. Conclusion	8
Annex	9

1 General Aspects

A reinforced masonry shell model was built at the Laboratory of the Structural Division, of the Civil Engineering Department from Minho University, as a result of a research aiming at defining adequate (micro-) concrete compositions to infill both masonry joints and shell topping.

For this purpose, the model geometry and the material characteristics were the following:

Mould: The formwork had a catenary geometric configuration with a span of 4m and a rise of 1m, see Figure 1. To assure masonry joints of equal width and to avoid brick slipping, timber strips with a cross section of 3mm height and 25mm width were fixed to the base of the mould. The timber strips in the longitudinal direction had a length of 1.10m, while the timber strips in the transversal direction had length of 1m, see Figure 2.

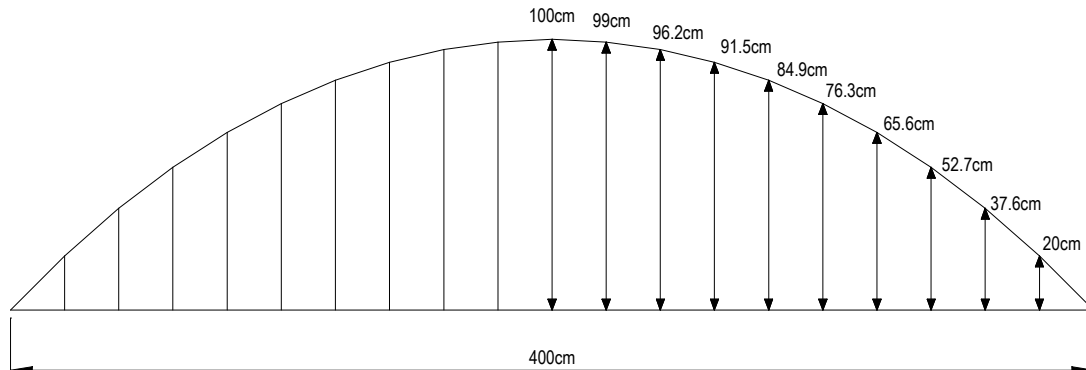


Figure 1 - Shell's mould of catenary geometry.

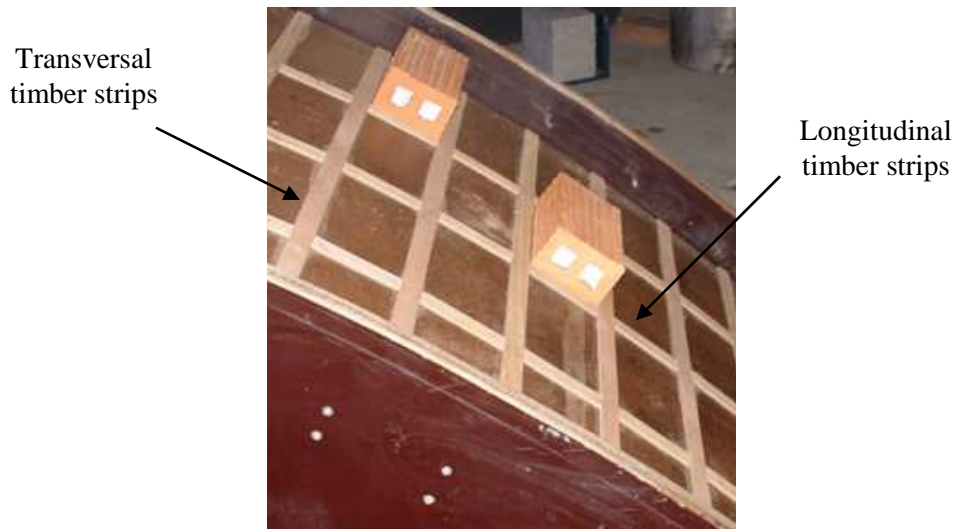


Figure 2 – Detail of the timber strips.

Concrete: The adopted concrete was composed by 300Kg/m^3 of cement, 279.32Kg/m^3 of sand 0.6-5mm, 654.70Kg/m^3 of sand 0.3-0.6mm and 805.79Kg/m^3 of gravel 5-10mm. The sieve curves of these aggregates are presented in the enclosed Annex. Rebuilt[®]1000 superplasticizer was used in a content of 2.5% of the cement quantity. Cement 52.5R of high initial strength was selected. The water/cement ratio was 0.55. Due to the facts that (i) masonry joints were narrow (only 25mm width), (ii) joints included conventional reinforcement and (iii) the shell model had a pronounced curvature, the concrete must have adjusted consistence to ensure good filling of the joints, without the presence of segregation of the aggregates and concrete slipping. The designed concrete has a slump of about 210mm, which seems adequate for these purposes.

Ceramic Bricks: In general, the brick dimensions were 215mm length, 100mm width and 65mm height. When the length of the bricks was bigger than 215mm, their faces were regularized to get the aforementioned maximum length. In this way, the bricks could be placed between the timber strips used to guarantee a joint width of 25mm. Polystyrene pieces were introduced in the extremities of the brick holes, to avoid excessive concrete penetration.

Main Reinforcement: Longitudinal and transversal reinforcement was made of steel bars of 8mm and 6mm diameter, respectively. The transversal reinforcement was placed each second transversal joints, while longitudinal reinforcement was placed in all longitudinal joints. Details of the cross sections are given in Figures 3 and 4. In the

concrete topping, immediately above the brick units, a welded wire mesh of bars of 3mm diameter, spaced at 75mm, was placed.

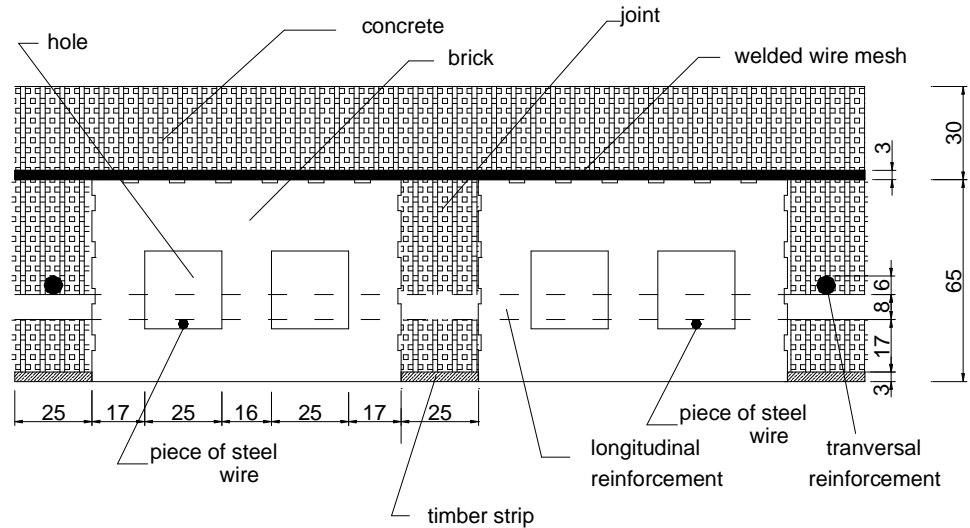


Figure 3 – Detail of longitudinal section (A-A in Fig 6) of brick masonry shell, (dimensions in mm).

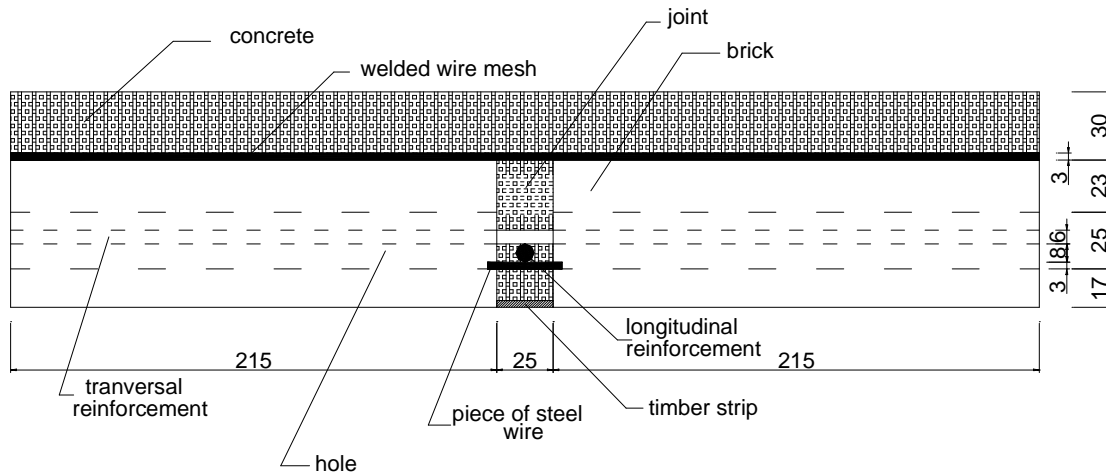


Figure 4 – Detail of transversal section (B-B in Fig 6) of brick masonry shell, (dimensions in mm).

2 Description of the Construction Process

Initially, a demoulding product was applied on the formwork top surface to facilitate the process of removing the shell from the formwork. Then, the bricks were placed between the strips and shown previously in Figure 2. After this procedure, some pieces of steel wire (“spacers”) were placed between the holes of adjacent bricks (see Fig. 4). The spacers provide support, maintain the longitudinal and the transversal reinforcement in place, and ensure a 20mm cover of concrete, see Figure 5(a). Finally, the joints were filled with concrete, see Figure 5(b). To guarantee adequate filling of the joints, manual compaction (no vibration) of the joints was made.

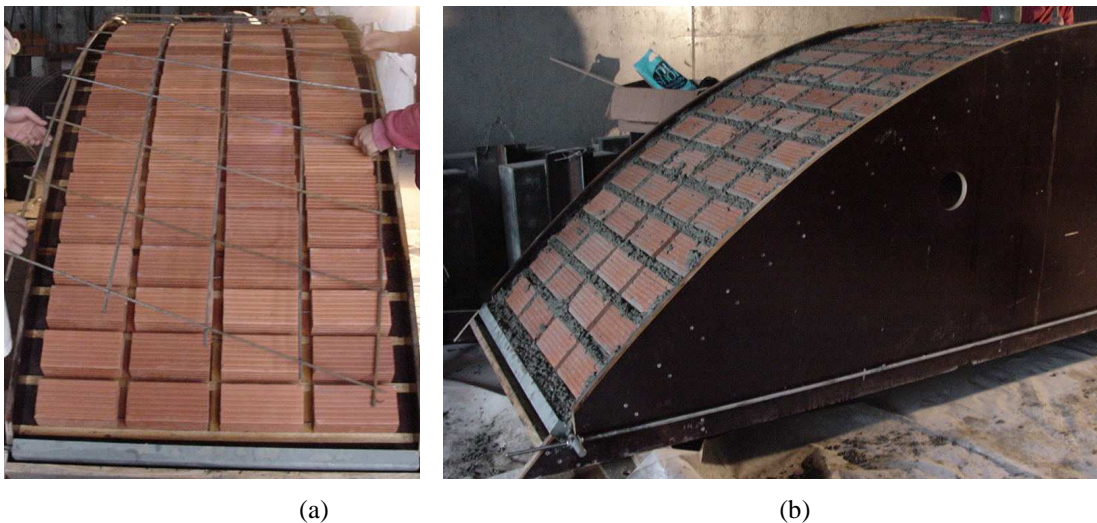


Figure 5 – Construction process: (a) Placing the longitudinal and transversal reinforcement;
(b) Joints infilled by concrete.

After filling the joints, the welded wire mesh was placed on the top surface of the brick units, see Figure 6.

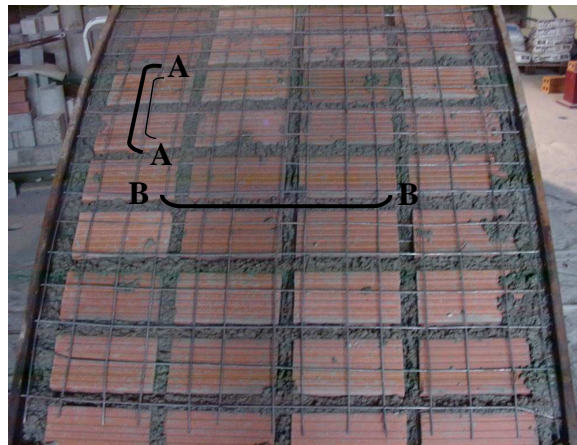


Figure 6 – Welded wire mesh positioned on the top surface of the brick unities (AA and BB indicate the cross section details on Figure 3 and 4).

In a second phase, a concrete layer of 30mm thickness was poured and compacted using vibration equipment, see Figure 7. After casting, the top surface of this layer was regularized with a ruler, in order to remove any concrete excess and to obtain a smooth surface, see Figure 8(a,b).

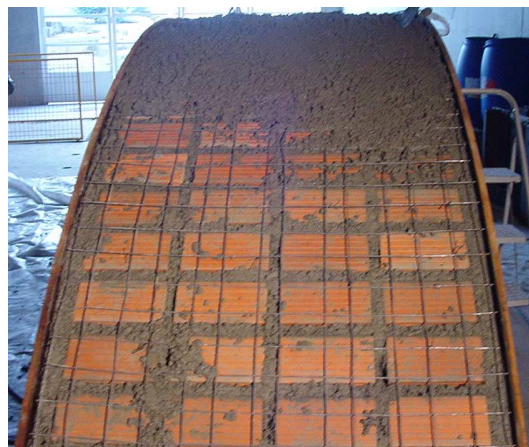


Figure 7 – Casting the top concrete layer.



(a)



(b)

Figure 8 – Shell finishing: (a) Removing excessive concrete; (b) Surface regularization.

3 Shell Appearance

Figure 9 shows the shell after construction. It is noted that during the curing process the humidity of shell surface was controlled and the formwork was removed twenty-four hours after the construction.



Figure 9 – View of the shell in the mould.

Figure 10(a) shows the shell after removing it from the mould. According to aesthetic requirements, concrete should not stain the bricks and concrete voids in the joints could not be accepted. Figure 10(b) reveals that this objective was perfectly accomplished. Moreover, the timber strips produce a 3 mm recess in the joint, which makes the finished product very appealing. It can be concluded the concrete consistence was adequate for this application, both for the topping and for the joints.



(a)



(b)

Figure 10 – (a) General view of the shell; (b) Appearance of the shell bottom surface.



4 Conclusion

A concrete composition of adequate slump was designed for reinforced masonry shells, applicable to reinforced joints of 25mm thickness and to a top layer of 30mm thick. To ensure that the joints are properly filled, manual compaction or a vibrator must be used, locally in joints, if possible.

With the proposed materials and techniques, no evidence of concrete slurry was observed in the brick faces and no evidence of joint concrete voids was found. The recesses in the transversal and in the longitudinal joints seem to result in an appealing shell finishing.



ANNEX



 UNIVERSIDADE DO MINHO DEPARTAMENTO DE ENGENHARIA CIVIL LABORATÓRIO DE ENGENHARIA CIVIL Azurém - 4800 Guimarães Telef. 510211/4 Fax 510217	ANÁLISE GRANULOMÉTRICA DE MATERIAIS INERTES AMOSTRA Nº: 1
	Requerente: JULIANA TORRES Obra: MEIA AREIA Lugar \ Rua: Freguesia: Concelho: Processo nº:

PENEIRAÇÃO

MATERIAL

DESCRIÇÃO DO MATERIAL

PESO TOTAL DA AMOSTRA (P1) g

PENEIROS		PESO RETIDO	% RETIDA	% RET.ACUMULADA	% PASSADA
3"	76,2				100,00
2"	50,8				100,00
1 1/2"	38,1				100,00
1"	25,4				100,00
3/4"	19,1				100,00
1/2"	12,7				100,00
3/8"	9,52				100,00
4	4,76	18,80	1,88	1,88	98,12
8	2,38	130,70	13,06	14,94	85,06
16	1,19	259,50	25,94	40,88	59,12
30	0,595	279,70	27,96	68,84	31,16
50	0,297	205,90	20,58	89,42	10,58
100	0,149	100,20	10,01	99,43	0,57
200	0,074	5,30	0,53	99,96	0,04
RESTO		0,40	0,04	100,00	0,00
TOTAL		1000,50		100,00	

ENSAIOU		OBSERVAÇÕES:
VERIFICOU		
DATA		

Sieve report for sand 0.6-5mm



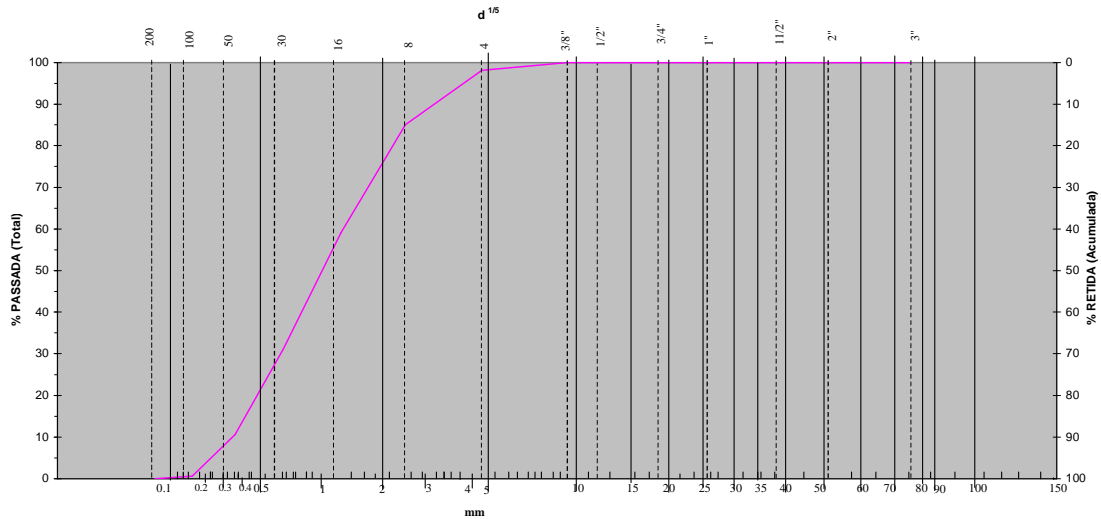
UNIVERSIDADE DO MINHO
DEPARTAMENTO DE ENGENHARIA CIVIL

LABORATÓRIO DE ENGENHARIA CIVIL
Azurém - 4800 Guimarães
Telef. 510211/4 Fax 510217

ANÁLISE GRANULOMÉTRICA DE MATERIAIS INERTES AMOSTRA Nº: 1

Requerente: JULIANA TORRES
Obra: MEIA AREIA
Lugar \ Rua:
Freguesia:
Concelho:
Processo nº:

CURVA GRANULOMÉTRICA



Sieve curve for sand 0.6-5mm



 UNIVERSIDADE DO MINHO DEPARTAMENTO DE ENGENHARIA CIVIL LABORATÓRIO DE ENGENHARIA CIVIL Azurém - 4800 Guimarães Telef. 510211/4 Fax 510217	ANÁLISE GRANULOMÉTRICA DE MATERIAIS INERTES AMOSTRA Nº: [REDACTED]
	Requerente: JULIANA TORRES Obra: AREIA FINA Lugar \ Rua: [REDACTED] Freguesia: [REDACTED] Concelho: [REDACTED] Processo nº: [REDACTED]

PENEIRAÇÃO

MATERIAL

DESCRIÇÃO DO MATERIAL

PESO TOTAL DA AMOSTRA (P1) g

PENEIROS		PESO RETIDO	% RETIDA	% RET.ACUMULADA	% PASSADA
3"	76,2				100,00
2"	50,8				100,00
1 1/2"	38,1				100,00
1"	25,4				100,00
3/4"	19,1				100,00
1/2"	12,7				100,00
3/8"	9,52				100,00
4	4,76				100,00
8	2,38				100,00
16	1,19				100,00
30	0,595	36,50	3,65	3,65	96,35
50	0,297	816,40	81,64	85,29	14,71
100	0,149	140,60	14,06	99,35	0,65
200	0,074	2,80	0,28	99,63	0,37
RESTO		3,70	0,37	100,00	-0,00
TOTAL		1000,00		100,00	

ENSAIOU		OBSERVAÇÕES:
VERIFICOU		
DATA		

Sieve report for sand 0.3-0.6mm



UNIVERSIDADE DO MINHO
DEPARTAMENTO DE ENGENHARIA CIVIL

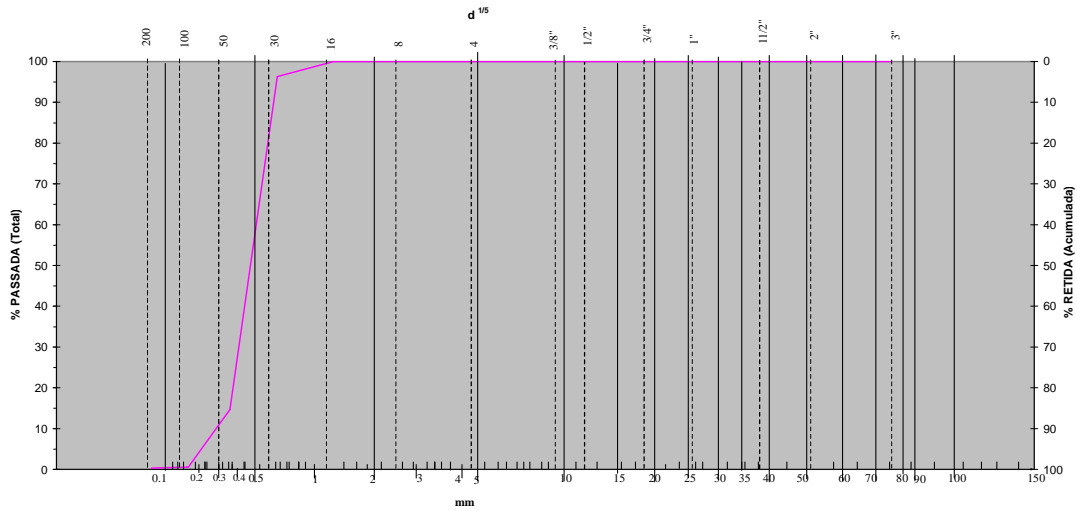
LABORATÓRIO DE ENGENHARIA CIVIL
Azurém - 4800 Guimarães
Telef. 510211/4 Fax 510217

ANÁLISE GRANULOMÉTRICA DE MATERIAIS INERTES AMOSTRA Nº:

Requerente: JULIANA TORRES
Obra: AREIA FINA


Lugar \ Rua:
Freguesia:
Concelho:
Processo nº:

CURVA GRANULOMÉTRICA



Sieve curve for sand 0.3-0.6mm



 UNIVERSIDADE DO MINHO DEPARTAMENTO DE ENGENHARIA CIVIL LABORATÓRIO DE ENGENHARIA CIVIL Azurém - 4800 Guimarães Telef. 510211/4 Fax 510217	ANÁLISE GRANULOMÉTRICA DE MATERIAIS INERTES AMOSTRA Nº: 1
	Requerente: JULIANA TORRES
	Obra: GRAVILHA 5/10
	Lugar \ Rua:
	Freguesia:
	Concelho:
Processo nº:	

PENEIRAÇÃO

MATERIAL: GRAVILHA 5/10

DESCRIÇÃO DO MATERIAL: GRAVILHA 5/10


PESO TOTAL DA AMOSTRA (P1): 2999 g

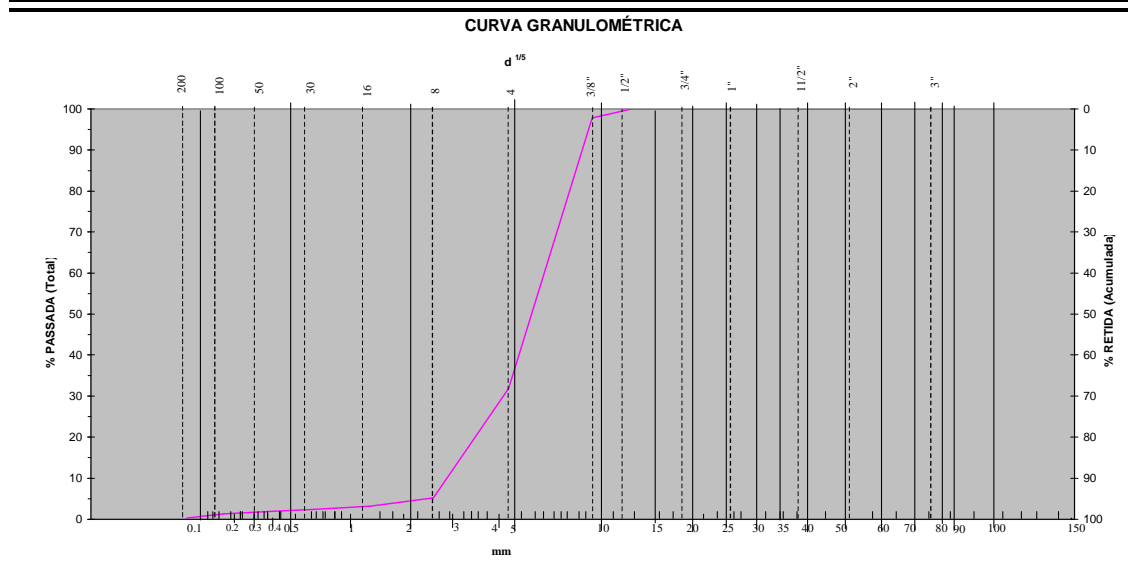
PENEIROS		PESO RETIDO	% RETIDA	% RET.ACUMULADA	% PASSADA
3"	76,2				100,00
2"	50,8				100,00
1 1/2"	38,1				100,00
1"	25,4				100,00
3/4"	19,1				100,00
1/2"	12,7				100,00
3/8"	9,52	64,30	2,14	2,14	97,86
4	4,76	1977,00	65,92	68,07	31,93
8	2,38	802,80	26,77	94,83	5,17
16	1,19	61,40	2,05	96,88	3,12
30	0,595	22,10	0,74	97,62	2,38
50	0,297	15,50	0,52	98,14	1,86
100	0,149	17,20	0,57	98,71	1,29
200	0,074	30,40	1,01	99,72	0,28
RESTO		8,30	0,28	100,00	-0,00
TOTAL		2999,00		100,00	

ENSAIOU		OBSERVAÇÕES:
VERIFICOU		
DATA		

Sieve report for gravel 5-10mm



 UNIVERSIDADE DO MINHO DEPARTAMENTO DE ENGENHARIA CIVIL LABORATÓRIO DE ENGENHARIA CIVIL Azurém - 4800 Guimarães Telef. 510211/4 Fax 510217	ANÁLISE GRANULOMÉTRICA DE MATERIAIS INERTES AMOSTRA Nº: 1
	Requerente: JULIANA TORRES Obra: GRAVILHA 5/10 Lugar \ Rua: Freguesia: Concelho: Processo nº:



Sieve curve for gravel 5-10mm