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# Study of brazilian structural concrete block conformity

# *Estudo da conformidade de blocos estruturais vazados de concreto simples fabricados no Brasil*


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## Abstract

This paper presents a study of the conformity of structural concrete blocks manufactured and used in masonry construction in Brazil. It is based on compressive strength tests, on dimensional analysis and absorption tests of over six thousand samples from three classes (A, B and C) and two modular sizes (M-15 and M-20). National results show that blocks tend to have an estimated compressive strength higher than specified, except blocks from class A. Regional results show that blocks manufactured in the northeast (NE) are consistently non-conforming, for all block classes. The study also shows that dimensional variations and absorption tests results are within code tolerances.

***Keywords***: structural concrete blocks, structural masonry, structural safety.

## Resumo

Este artigo apresenta um estudo da conformidade de blocos estruturais vazados de concreto simples fabricados e empregados na execução de estruturas de alvenaria no Brasil. O estudo está baseado em resultados de ensaios de resistência à compressão, de análises dimensionais e de ensaios de absorção realizados em mais de seis mil amostras pertencentes a três classes (A, B e C) e duas famílias de modulação (M-15 e M-20). Resultados nacionais mostram que os blocos tendem a apresentar resistência característica estimada superior à resistência característica especificada, exceto aqueles pertencentes à classe A. Resultados regionais revelam que blocos fabricados na região nordeste estão sistematicamente não-conformes, em todas as classes de resistência investigadas. O estudo ainda revela que a variação nas dimensões dos blocos é desprezível, que os desvios encontrados atendem com folga às tolerâncias de referência e que valores de absorção média estão dentro do permitido.

***Palavras-chave:*** blocos estruturais de concreto, alvenaria estrutural, segurança das estruturas.

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## 1. Introduction

This article presents an investigation about the conformity of structural concrete blocks manufactured and used in masonry construction in Brazil. This study is based on results from different regions of the country. Its spatial distribution is in accordance with the location of manufacturers certified by the quality program of the Brazilian Portland Cement Association (ABCP) and associated to the Brazilian Association of Concrete Blocks Industry (BLOCO BRASIL).
The study is based on tests performed in more than 6 thousand blocks divided into three Classes (A, B and C) and two modular sizes (M-15 and M-20). Class A blocks have compressive strength greater than 8 MPa, Class B blocks have compressive strength between 4 and 8 MPa and Class C blocks have compressive strength greater than 3 MPa. Modular size M-15 blocks have width of 140 mm, while modular size M-20 blocks have width of 190 mm.
This paper studies the compressive strength ($f_b$), width (W), length (L), height (H), thickness (T), gross area (A) and absorption ($A_b$) of concrete blocks. The entire study is based on current national normalization, especially the codes for simple concrete masonry blocks [1], test methods for simple concrete masonry blocks [2], structural masonry design with concrete blocks [3] and control and execution of structural masonry works with concrete blocks [4].
This research is part of a larger project about the calibration, based on structural reliability, of the partial safety factors of Brazilian design codes. The calibration is being developed by the authors of this paper, in a continuation to studies in Beck and Doria [5], Beck et al. [6], Chaves et al. [7] and Beck and Souza Jr. [8].
Although the results of this work serve a larger purpose, there is value in themselves, as they indicate the quality of concrete blocks manufactured in different regions of the country. The number of samples evaluated may not be as large as desired, but this is by far the largest survey about concrete blocks made in Brazil.

## 2. Relevance

The structural masonry with concrete blocks is a constructive system that has gained space in the Brazilian civil construction industry, precisely because it allows a reduction in the completion time of the constructions and an economy in the final cost of the projects. In 2013, for instance, the Brazilian industrial park was prepared to produce 100 million concrete blocks [9].
Despite the great acceptance by construction companies, problems with the low quality of concrete blocks are common, and this results in larger consumption of mortar, the frequent breaking of blocks during handling and the appearance of pathological manifestations in the ready masonry [10, 11].
Many manufacturers do not have adequate dosing, curing and control procedures for the blocks produced at their facilities [12]. In this way, it is important to carry out researches that evaluate the quality of the concrete blocks manufactured and sold in the national market.
In the literature, there isn't much work about the conformity of Brazilian structural concrete blocks; and the few that exist have limited scope. Among those, it is worth mentioning Martins et al. [11], Sander [12], Lordsleem Júnior et al. [13], Cerqueira et al. [14] and Cerqueira et al. [15]. The blocks evaluated in these studies presented compressive strength lower than recommended and absorption larger than expected, although they presented dimensional conformance.

## 3. Origin and database classification

This work is based on the analysis of 6,474 structural concrete blocks manufactured between 2010 and 2016 in three of the five regions of Brazil, as detailed in Table 1. These three regions - South (S), Southeast (SE) and Northeast (NE) - concentrate the largest number of factories and constructions using the structural masonry system.
The blocks are divided into three Classes (A, B and C), following Table 2. The results have a strong relation with the Classes usually used in each region. In the South and Southeast regions, for example, Class A blocks are more used than in the Northeast; on the other hand, in the Southeast and Northeast regions there is greater use of Class B blocks than in the South.
In addition to the division by Classes, the blocks are classified into two modular sizes (M-15 and M-20), following Table 3. These data give an idea of the modular sizes that are usual in each region of the country. In the South, for instance, there is smaller use of modular size M-20 blocks than in the Southeast and Northeast regions; there is uniform use of modular size M-15 blocks in all regions.
Finally, the data used in this study come from 14 manufacturers,

**Table 1**
Quantification of the specimens by Brazilian regions

| Test | Region | Quantity | Percentage |
|---|---|---|---|
| $f_b$, L, C, H, E and A | S | 433 | 8 |
| | SE | 2948 | 55 |
| | NE | 2005 | 37 |
| | Total | 5386 | 100 |
| $A_b$ | S | 81 | 8 |
| | SE | 447 | 41 |
| | NE | 560 | 51 |
| | Total | 1088 | 100 |

**Table 2**
Quantification of the specimens by classes

| Test | Class | Quantity | Percentage |
|---|---|---|---|
| $f_b$, L, C, H, E and A | A | 1044 | 20 |
| | B | 1740 | 32 |
| | C | 2602 | 48 |
| | Total | 5386 | 100 |
| $A_b$ | A | 255 | 23 |
| | B | 570 | 52 |
| | C | 263 | 25 |
| | Total | 1088 | 100 |

**Table 3**
Quantification of the specimens by modular sizes

| Test | Modular size | Quantity | Percentage |
|---|---|---|---|
| $f_b$, L, C, H, E and A | M-15 | 3718 | 69 |
| | M-20 | 1668 | 31 |
| | Total | 5386 | 100 |
| $A_b$ | M-15 | 387 | 36 |
| | M-20 | 701 | 64 |
| | Total | 1088 | 100 |

3 from the South region, 5 from the Southeast region and 6 from the Northeast Region. The results were collected directly from some of these manufacturers, and indirectly from others through accredited technological control laboratories. Four of the 14 manufacturers are not members of BLOCO BRASIL and not certified by the ABCP quality program.

## 4. Methodology and database treatment

This work is based on compressive strength tests, on dimensional analysis and absorption tests performed on structural concrete block samples. The compressive tests involve determining the strength of the blocks (fb). The dimensional analysis consists of the measurement of the width (L), length (C), height (H), wall thickness (E) and gross area (A) of the blocks. The water absorption test corresponds to the determination of the relationship between the mass of water contained in the saturated block and the mass of the dry block ($A_b$).

The random nature of the mechanical, dimensional and physical properties of blocks requires a statistical approach to the problem; which results in the determination of a mean (μ), a standard deviation (σ) and a coefficient of variation (C.V.). The mean was calculated through the sum of all samples divided by the total number. The standard deviation, which represents the regularity and dispersion of the results in relation to the mean, was found from the square root of the sample variance. The coefficient was calculated from the ratio between the standard deviation and the mean.

As the objective of this study is to obtain statistical descriptions that generically represent concrete blocks produced in Brazil, the data from different regions is grouped and analyzed together. Therefore, the national statistics were obtained from regional statistical weights, which were applied according to the number of samples available for each Class and modular size in each region of the country. Eq. 1 shows the expression used in the weighting calculations.

$$\text{National}_{\text{Result}} = \sum(\text{Regional}_{\text{Result}}.\text{Weight}) \quad (1)$$

It is worth mentioning this works also involved a previous statistical analysis of the samples in order to eliminate data that does not belong to the group. In this way, the box-and-whiskers representations was used, which is a tool oriented to the detection of spurious data. This step was important to avoid possible distortions in the results due to the inclusion of outliers.

### 4.1 Compressive strength

The compressive strength quality control process involves tests carried out on samples that vary according to the batch size and the criteria of items 6.5.1 and 6.5.2 from the code requirements for simple concrete masonry blocks [1]. The batches can have 5,000 thousand blocks, between 5001 and 10,000 blocks and more than 10,000 blocks. In the first case a minimum number of 4 to 6 samples is established, depending on the criterion used; in the second a minimum number of 5 to 8 samples is defined; and in the third one, a minimum number of 6 to 10 samples is defined.

In practical terms, a reference value is defined for the strength of the concrete blocks and it is used in the batch conformity assessment. The reference value, named characteristic compressive strength ($f_{bk}$), represents a boundary that must be exceeded by at least 95% of the blocks tested. At the end of the quality control process, a batch is considered good when the estimated value of its characteristic resistance ($f_{bkest}$) satisfies the relation presented in Eq. 2.

$$f_{bkest} \geq f_{bk} \quad (2)$$

From the increasing order of the samples (f1 < f2 < f3 < … < fn) it was possible to estimate the characteristic strength ($f_{bkest}$) based on the result corresponding to 5% percentile, as can be seen in Eq. 3.

$$f_{bkest} = f_{int[0.05]} \quad (3)$$

In addition to the characteristic strength ($f_{bkest}$), the average strength ($f_{bm}$) and the standard deviation (σ) of the samples that compose the database were also estimated. In order to compare different Classes and families of modulation, the results are expressed in terms of the ratio between the estimated characteristic strength and the specified characteristic strength ($f_{bkest}/f_{bk}$), the ratio between the average strength and the characteristic strength ($f_{bm}/f_{bk}$) and the coefficient of variation (C.V.).

### 4.2 Dimensional analysis

The quality control process also involves a dimensional analysis of samples to determine the width (W), length (L), height (H), thickness (T) and gross area (A). The number of samples is a function of the batch size, as discussed previously. It is worth mentioning that a batch is limited to 40,000 blocks manufactured on the same day.

The code requirements for simple concrete masonry blocks [1] establishes a tolerance of ± 2.0 mm for the width, and ± 3.0 mm for the length and height of the samples. This code indicates that blocks from Classes A and B must have a minimum thickness of 32 mm, when they belong to modular size M-20; and 25 mm, when they belong to modular size M-15. Blocks from Class C shall have a minimum thickness of 18 mm. In other hand, this code defines that the transverse walls from A and B Class blocks must be at least 25 mm thick, and that the transverse walls of C Class blocks must be at least 18 mm thick.

### 43 Absorption

The quality control process also involves the absorption tests that must be carried out in at least 3 samples per batch. The code for

requirements standard for simple concrete masonry blocks [1] states that the average absorption ($A_{bm}$) must not exceed 6% for Class A blocks, 8% for Class B blocks and 10% for Class C blocks. This code also defines that individual absorption should be less than 8% for Class A blocks, 10% for Class B blocks and 12% for Class C blocks.
In the case of blocks made of lightweight aggregates, the code requirements for simple concrete masonry blocks [1] determines, for all Classes, that the average absorption ($A_{bm}$) should be less than 13%, and that individual absorption should be less than 16%.

## 5. Results

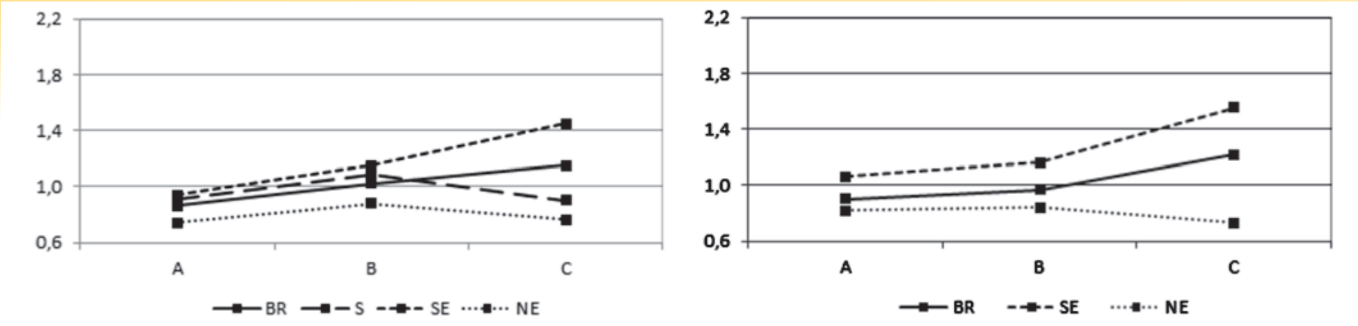
This section presents results obtained from the statistical treatment of the test data of 6,474 concrete blocks manufactured between the years of 2010 and 2016 in different regions of the country.

### *5.1 Compressive strength*

Table 4 presents a summary of the results for the compressive strength. With respect to national results, this table shows that Class A blocks have estimated characteristic strength lower than the specified resistance ($f_{bkest} < f_{bk}$), as the ratio between estimated and specified characteristic strengths is lower than one ($f_{bkest}/f_{bk} < 1.0$). Hence, Class A blocks do not comply with strength requirements, national wise. Blocks from classes B and C show conformity w.r.t. required strength nationally, but strong dispersion of results is observed among Brazilian regions. Strength of blocks produced and used in the north-east (NE) is consistently below code requirements, for all Classes and modulation groups.
From Table 4 it is also possible to verify that Class C blocks tend to present greater average-to-characteristic strength ratio than Class B blocks, which in turn present a higher ratio than the Class A blocks. On the other hand, Class A blocks tend to have a lower coefficient of variation than Class B blocks, which in turn tend to have a lower coefficient of variation than Class C blocks.
It is also possible to verify from Table 4 that modular size M-15 blocks tend to present higher average-to-characteristic strength ratio, whereas modular size M-20 blocks tend to present higher estimated-to-specified characteristic strength ratio. This situation is directly related to the lower dispersion of the results from the modular size M-20 blocks, since the coefficients of variation of the modular size M-15 blocks are larger.

**Table 4**
Compressive strength results by brazilian regions

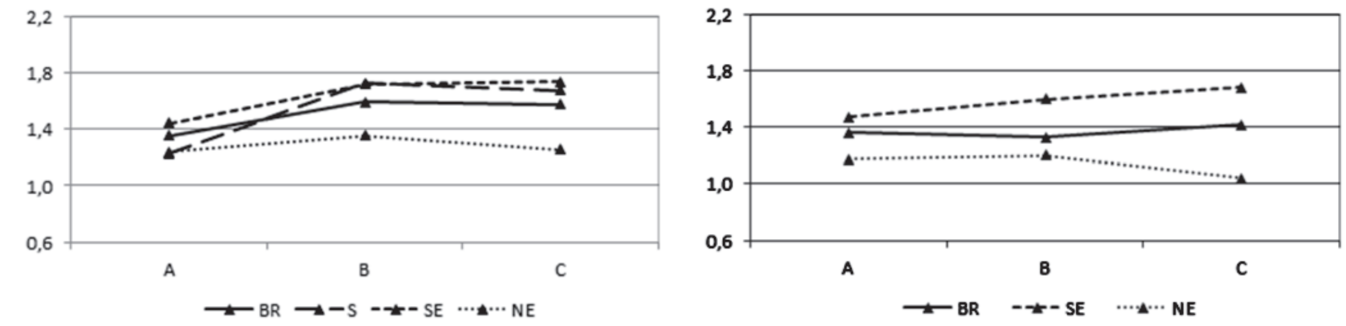
| Class | Modular size | Region | $f_{bkest}$ / $f_{bk}$ | $f_{bm}$ / $f_{bk}$ | C.V. |
|---|---|---|---|---|---|
| A | M-15 | S | 0,909 | 1,226 | 0,220 |
| | | SE | 0,940 | 1,447 | 0,260 |
| | | NE | 0,743 | 1,239 | 0,190 |
| | | BR | 0,860 | 1,358 | 0,239 |
| | M-20 | S | – | – | – |
| | | SE | 1,065 | 1,470 | 0,185 |
| | | NE | 0,818 | 1,239 | 0,219 |
| | | BR | 0,900 | 1,364 | 0,197 |
| **Class** | **Modular size** | **Region** | $f_{bkest}$ / $f_{bk}$ | $f_{bm}$ / $f_{bk}$ | **C.V.** |
| B | M-15 | S | 1,085 | 1,727 | 0,261 |
| | | SE | 1,153 | 1,723 | 0,270 |
| | | NE | 0,878 | 1,357 | 0,281 |
| | | BR | 0,990 | 1,592 | 0,279 |
| | M-20 | S | – | – | – |
| | | SE | 1,163 | 1,598 | 0,302 |
| | | NE | 0,839 | 1,202 | 0,222 |
| | | BR | 1,023 | 1,328 | 0,248 |
| **Class** | **Modular size** | **Region** | $f_{bkest}$ / $f_{bk}$ | $f_{bm}$ / $f_{bk}$ | **C.V.** |
| C | M-15 | S | 0,903 | 1,678 | 0,360 |
| | | SE | 1,449 | 1,738 | 0,230 |
| | | NE | 0,765 | 1,259 | 0,393 |
| | | BR | 1,150 | 1,566 | 0,294 |
| | M-20 | S | – | – | – |
| | | SE | 1,556 | 1,684 | 0,144 |
| | | NE | 0,728 | 1,040 | 0,331 |
| | | BR | 1,215 | 1,419 | 0,221 |




a) Modular size M-15

b) Modular size M-20

**Figure 1**
Ratios between estimated and specified characteristic strength ($f_{bkest}/f_{bck}$) by modular sizes




a) Modular size M-15

b) Modular size M-20

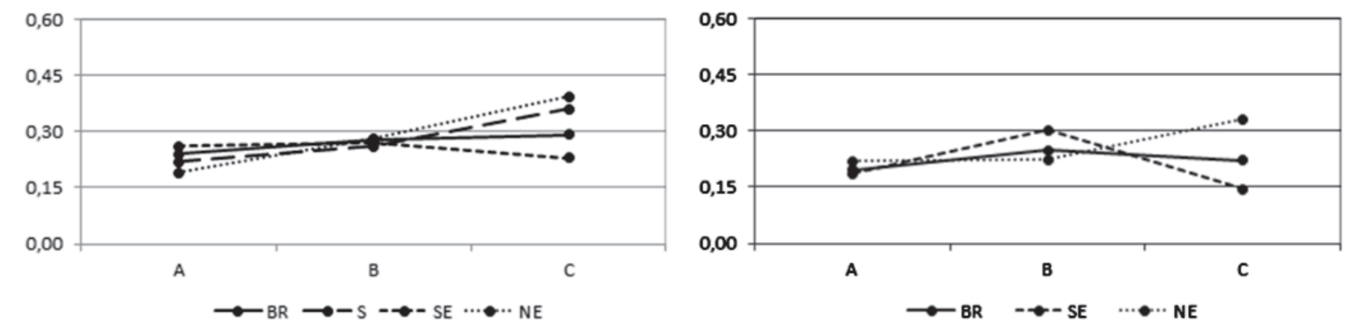
**Figure 2**
Ratio between average and specified characteristic strength ($f_{bm}/f_{bck}$) by modular sizes

The blocks evaluated by Stewart and Lawrence [16] in Australia showed a ratio between estimated and specified characteristic strengths ($f_{bkest}/f_{bk}$) between 0.83 and 1.27. Back to Brazil, Cerqueira et al. [14] obtained ratios ($f_{bkest}/f_{bk}$) of around 0.80.

Figure 1, based on Table 4, shows variation of the ratio between estimated–to-specified characteristic strengths ($f_{bkest}/f_{bk}$) for different regions, as well as for Brazil. This figure shows that the modular size M-15 blocks manufactured in the Northeast region do not present conformity of compressive strength in the three Classes analyzed; while blocks manufactured in the South region do not present conformity in Classes A and C, and blocks manufactured in the Southeast region do not present conformity in Class A. Figure 1 also shows that modular size M-20 blocks manufactured in the Northeast do not present conformity in any of Classes, unlike the blocks manufactured in the Southeast that present conformity in all the Classes. The behavior observed in Figure 1 reproduces results obtained in studies about the Brazilian concrete conformity [17, 18, 19].

Figure 2, based on Table 4, shows the variation of the ratio of average-to-specified characteristic strengths ($f_{bm}/f_{bk}$) for Brazil and its studied regions. This figure shows that, in both modular sizes, average strength is higher than characteristic strength in all regions, as expected, although the blocks manufactured in the southeast region tend to present better results than the blocks manufactured in other regions.

Figure 3, based on Table 4, shows the coefficient of variation (C.V.) for the three regions studied and for Brazil. This figure makes clear




a) Modular size M-15

b) Modular size M-20

**Figure 3**
The coefficient of variation (C.V.) of compressive strength by modular sizes

that in both modular sizes there is a greater difference between the results from Class C blocks; however, Figure 3 indicates that there is a smaller difference between the results from modular size M-15 blocks in Class B, followed by the modular size M-20 blocks in Class A. Although Class A blocks tend to have a smaller estimated strength and a lower average strength, Figure 3 makes clear that these same blocks have less dispersion in their results indicating that there is less variability among them. Stewart and Laerence [16] obtained coefficients of variation (C.V.) around 0.19, which are in line with the values found in this study and in studies about the conformance of concretes manufactured in Brazil [17,18, 19, 20].

### 5.2 Dimensional analysis

Table 5 presents results obtained for the concrete blocks dimensions, at regional and national level. In order to compare blocks with different sizes, the results are expressed in terms of the ratio between average and nominal width ($W_m/W_{nom}$), ratio of average and nominal length ($L_m/L_{nom}$), ratio between mean and nominal height ($H_m/H_{nom}$) and the standard deviations (σ) of these metrics.
In Table 5 it is possible to verify that, regardless of the region considered, in all Classes and modular sizes, the variation in the blocks dimensions is small and the deviations found meet the tolerances imposed by code requirements for simple concrete masonry blocks [1].
Table 6 presents a summary of the results found for the longitudinal and transverse thicknesses of the blocks manufactured in the three regions studied and in Brazil. In order to compare blocks with different thicknesses, the results are expressed in terms of the ratio between average and nominal thickness ($T_m/T_{nom}$), coefficient of variation (C.V.) and percentage of samples with thickness smaller than that established in code requirements [1].
Table 6 makes clear that blocks from all Classes and modular sizes present thicknesses that tend to exceed the reference values defined in the code. This table allows verifying that the blocks present small variability in their thicknesses, since the values of the coefficients of variation are small. This table also allows concluding that the percentage of nonconforming samples tends to zero; being 1% among modular size M-15 from Class A, and 2% among modular size M-15 from Class B.
The results shown in Table 6 allow one to conclude that, in all Classes and modular sizes, the thicknesses of the walls tend to exceed the reference values established in the code, being proportionally larger among modular size M-15 from Class C. This table allows verifying that blocks present small variability in their thicknesses, since the values of the coefficients of variation are not very large. This table also allows concluding that the percentage of nonconforming samples tends to zero; being 1% among modular size M-15 from Class A, and 2% among modular size M-15 from Class B.
Finally, Table 7 presents a summary of the results found for the gross area of the blocks, at both national and regional level. In order to allow a comparison between blocks with different gross areas, the results are expressed in terms of the ratio between average and nominal gross area ($A_m/A_{nom}$) and the coefficient of variation (C.V.). Results presented in Table 7 show that, regardless of

**Table 5**
Dimensional analysis results by brazilian regions

| Class | Modular size | Region | $W_m$ / $W_{nom}$ | $\sigma_L$ (mm) | $L_m$ / $L_{nom}$ | $\sigma_C$ (mm) | $H_m$ / $H_{nom}$ | $\sigma_H$ (mm) |
|---|---|---|---|---|---|---|---|---|
| A | M-15 | S | 1,002 | 0,75 | 1,002 | 1,73 | 1,000 | 1,58 |
| | | SE | 1,002 | 0,60 | 1,001 | 1,43 | 1,001 | 1,04 |
| | | NE | 1,004 | 0,83 | 1,003 | 1,08 | 1,003 | 0,92 |
| | | BR | 1,003 | 0,66 | 1,001 | 1,40 | 1,001 | 1,06 |
| | M-20 | S | – | – | – | – | – | – |
| | | SE | 1,000 | 0,36 | 1,000 | 0,52 | 0,998 | 0,57 |
| | | NE | 1,005 | 0,83 | 1,004 | 1,13 | 1,005 | 0,93 |
| | | BR | 1,002 | 0,53 | 1,001 | 0,73 | 1,001 | 0,71 |

| Class | Modular size | Region | $W_m$ / $W_{nom}$ | $\sigma_L$ (mm) | $L_m$ / $L_{nom}$ | $\sigma_C$ (mm) | $H_m$ / $H_{nom}$ | $\sigma_H$ (mm) |
|---|---|---|---|---|---|---|---|---|
| B | M-15 | S | 1,017 | 8,24 | 1,004 | 2,51 | 0,990 | 3,31 |
| | | SE | 1,000 | 5,21 | 1,001 | 0,70 | 1,000 | 0,96 |
| | | NE | 1,004 | 0,86 | 1,003 | 1,13 | 1,003 | 1,10 |
| | | BR | 1,003 | 3,57 | 1,002 | 0,94 | 1,001 | 1,10 |
| | M-20 | S | – | – | – | – | – | – |
| | | SE | 1,001 | 0,52 | 1,000 | 0,77 | 1,000 | 0,70 |
| | | NE | 1,002 | 2,62 | 1,003 | 1,09 | 1,004 | 1,11 |
| | | BR | 1,002 | 1,96 | 1,002 | 0,99 | 1,002 | 0,98 |

| Class | Modular size | Region | $W_m$ / $W_{nom}$ | $\sigma_L$ (mm) | $L_m$ / $L_{nom}$ | $\sigma_C$ (mm) | $H_m$ / $H_{nom}$ | $\sigma_H$ (mm) |
|---|---|---|---|---|---|---|---|---|
| C | M-15 | S | 1,011 | 1,25 | 1,006 | 8,37 | 0,990 | 2,81 |
| | | SE | 1,001 | 0,40 | 1,000 | 0,52 | 1,000 | 0,83 |
| | | NE | 1,010 | 7,89 | 1,001 | 0,53 | 1,001 | 1,12 |
| | | BR | 1,005 | 2,92 | 1,001 | 1,27 | 0,999 | 1,11 |
| | M-20 | S | 1,002 | 1,08 | 1,003 | 0,85 | 0,998 | 1,27 |
| | | SE | 1,000 | 0,41 | 1,000 | 0,29 | 0,999 | 0,46 |
| | | NE | 1,002 | 0,53 | 1,001 | 0,58 | 1,001 | 0,77 |
| | | BR | 1,001 | 0,48 | 1,001 | 0,42 | 1,000 | 0,60 |

**Table 6**
Thickness results by brazilian regions

| Class | Modular size | Region | $T_m$ / $T_{nom}$ | C.V. | % nonconforming samples |
|---|---|---|---|---|---|
| A | M-15 | S | – | – | – |
| | | SE | 1,065 | 0,031 | 1 |
| | | NE | – | – | – |
| | | BR | 1,065 | 0,031 | 1 |
| | M-20 | S | – | – | – |
| | | SE | 1,187 | 0,118 | 0 |
| | | NE | – | – | – |
| | | BR | 1,187 | 0,118 | 0 |

| Class | Modular size | Region | $T_m$ / $T_{nom}$ | C.V. | % nonconforming samples |
|---|---|---|---|---|---|
| A | M-15 | S | – | – | – |
| | | SE | 1,062 | 0,030 | 3 |
| | | NE | 1,030 | 0,037 | 2 |
| | | BR | 1,058 | 0,031 | 2 |
| | M-20 | S | – | – | – |
| | | SE | 1,147 | 0,127 | 0 |
| | | NE | 1,062 | 0,021 | 0 |
| | | BR | 1,092 | 0,059 | 0 |

| Class | Modular size | Region | $T_m$ / $T_{nom}$ | C.V. | % nonconforming samples |
|---|---|---|---|---|---|
| A | M-15 | S | – | – | – |
| | | SE | 1,142 | 0,075 | 0 |
| | | NE | 1,339 | 0,071 | 0 |
| | | BR | 1,269 | 0,072 | 0 |
| | M-20 | S | 1,216 | 0,041 | 0 |
| | | SE | 1,194 | 0,101 | 0 |
| | | NE | 1,369 | 0,055 | 0 |
| | | BR | 1,336 | 0,062 | 0 |

the Class or modular size, the variation in the gross area is small; which is reflected in ratios of average-to-nominal gross areas approximately equal to one ($A_m/A_{nom} \approx 1.0$) and in small coefficients of variations.

### *5.3 Absorption*

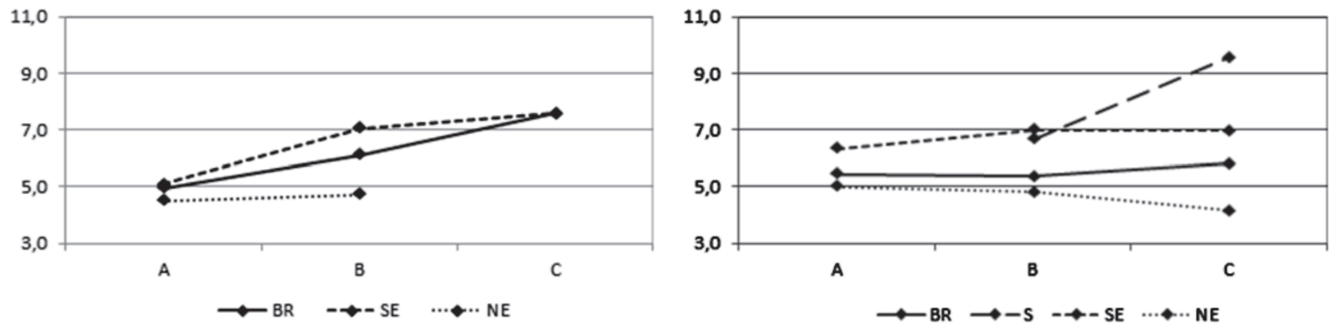
Table 8 presents a summary of the results for the blocks absorption. This table shows that in all cases the average absorption ($A_{bm}$) was lower than the limits imposed by code requirements for simple concrete masonry blocks [1], although there were blocks with individual absorption higher than the permitted.
Figure 4, based on Table 8, shows the average absorption ($A_{bm}$) for the different regions, as well as for Brazil. As expected, this figure shows that Class C blocks tend to have higher average absorption than Class B blocks, which in turn tend to have a higher average absorption than Class A blocks.
Figure 5, based on Table 8, shows the coefficient of variation (C.V.) for the three regions and Brazil. Contrary to expectations, this figure shows that Class A blocks tend to have higher coefficient of variation than Class B blocks, which in turn tend to have a higher coefficient of variation than Class C blocks. This result is clearly reflected in the percentage of nonconforming samples.
Curiously, the blocks manufactured in the Northeast tend to have a lower average absorption ($A_{bm}$) than the blocks manufactured in other regions; but this does not mean that these blocks have higher quality, since they also tended to have a higher coefficient of variation (C.V.).

## 6. Conclusions

This work presented a study of conformity of Brazilian structural concrete blocks. The study was based on results of compressive strength tests, dimensional analysis and absorption tests of over six thousand samples from three Classes (A, B and C) and two modular sizes (M-15 and M-20).
National results showed that blocks from Class A have estimated characteristic strength smaller than specified strengths; hence, that these blocks are not compliant to code requirements. Blocks from Classes B and C showed conformity in the national analysis, but regional variations are very significant. Blocks manufactured in the north-east (NE) were found to be consistently non-compliant, for all classes.
Results also showed that modular size M-15 blocks presented higher ratios of average-to characteristic strength, while modular size M-20 blocks presented higher ratios of estimated-to-specified characteristic strength.
Regarding the dimensional analysis, national and regional results showed that the blocks from all the Classes and families presented conformity, since they presented acceptable variations in their dimensions.
Regarding the absorption tests, results showed that in all Classes and families of modulation the average absorption was lower than limit values, although individually-nonconforming blocks were observed.
Results presented in this paper illustrate the problem of non-conformity of Brazilian structural concrete blocks and emphasize the

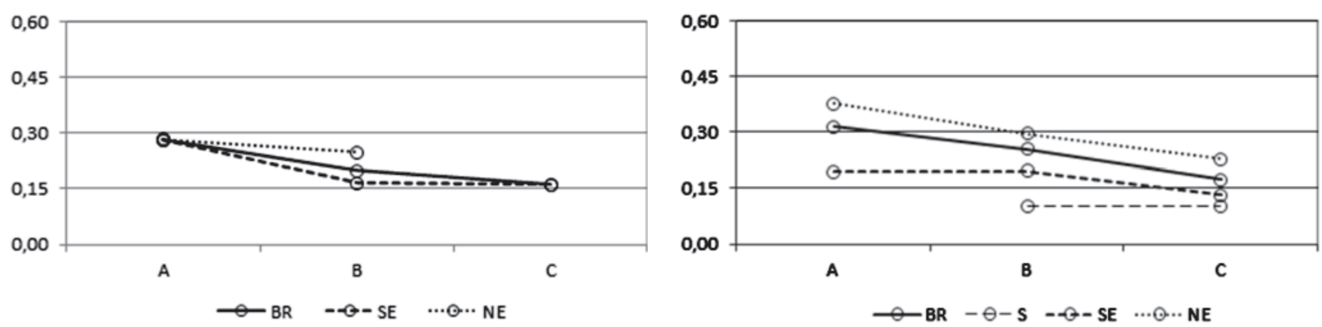
**Table 7**
Gross area results by brazilian regions

| Class | Modular size | Region | $A_m$ / $A_{nom}$ | C.V. |
|---|---|---|---|---|
| A | M-15 | S | 1,009 | 0,008 |
| | | SE | 1,003 | 0,005 |
| | | NE | 1,007 | 0,007 |
| | | BR | 1,004 | 0,006 |
| | M-20 | S | – | – |
| | | SE | 1,000 | 0,002 |
| | | NE | 1,010 | 0,006 |
| | | BR | 1,004 | 0,003 |
| **Class** | **Modular size** | **Region** | **$A_m$ / $A_{nom}$** | **C.V.** |
| B | M-15 | S | 1,013 | 0,017 |
| | | SE | 1,003 | 0,005 |
| | | NE | 1,008 | 0,008 |
| | | BR | 1,006 | 0,007 |
| | M-20 | S | – | – |
| | | SE | 1,001 | 0,003 |
| | | NE | 1,008 | 0,006 |
| | | BR | 1,005 | 0,005 |
| **Class** | **Modular size** | **Region** | **$A_m$ / $A_{nom}$** | **C.V.** |
| C | M-15 | S | 1,012 | 0,073 |
| | | SE | 1,000 | 0,031 |
| | | NE | – | – |
| | | BR | 1,002 | 0,038 |
| | M-20 | S | 1,004 | 0,006 |
| | | SE | 1,000 | 0,002 |
| | | NE | – | – |
| | | BR | 1,000 | 0,003 |




a) Modular size M-15 b) Modular size M-20

**Figure 4**
The average absorption ($A_{bm}$) by modular sizes




a) Modular size M-15 b) Modular size M-20

**Figure 5**
The coefficient of variation (C.V.) for absorption by modular sizes

**Table 8**
Absorption analysis results by Brazilian regions

| Class | Modular size | Region | $A_{bm}$ (%) | C.V. | % nonconforming samples |
|---|---|---|---|---|---|
| A | M-15 | S | – | – | – |
| | | SE | 5,10 | 0,281 | 3 |
| | | NE | 4,52 | 0,283 | 1 |
| | | BR | 4,96 | 0,282 | 2 |
| | M-20 | S | – | – | – |
| | | SE | 6,33 | 0,194 | 6 |
| | | NE | 5,02 | 0,376 | 5 |
| | | BR | 5,46 | 0,315 | 4 |

| Class | Modular size | Region | $A_{bm}$ (%) | C.V. | % nonconforming samples |
|---|---|---|---|---|---|
| B | M-15 | S | – | – | – |
| | | SE | 7,05 | 0,166 | 2 |
| | | NE | 4,72 | 0,249 | 0 |
| | | BR | 4,96 | 0,281 | 1 |
| | M-20 | S | 6,68 | 0,101 | 0 |
| | | SE | 7,01 | 0,196 | 2 |
| | | NE | 4,81 | 0,296 | 0 |
| | | BR | 5,37 | 0,255 | 0,5 |

| Class | Modular size | Region | $A_{bm}$ (%) | C.V. | % nonconforming samples |
|---|---|---|---|---|---|
| C | M-15 | S | – | – | – |
| | | SE | 7,59 | 0,160 | 0 |
| | | NE | – | – | – |
| | | BR | 7,59 | 0,160 | 0 |
| | M-20 | S | 9,56 | 0,100 | 0 |
| | | SE | 6,97 | 0,132 | 0 |
| | | NE | 4,15 | 0,227 | 0 |
| | | BR | 5,82 | 0,173 | 0 |

importance of rigorous quality control in manufacturing and receiving processes.

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