DEVELOPMENT AND USE OF A NEW TYPE OF CONCRETE MASONRY UNIT

Massetto, Leonardo Tolaine¹; Tauil, Carlos Alberto³; Guimarães, Mário Sergio⁴

¹ MSc, Civil Engineer, leonardo@glasser.com.br  
² Architect Carlos Alberto Tauil, carlosalberto.taul@gmail.com  
³ Comercial Manager, Glasser Pisos e Pré-Moldados, mario@glasser.com.br

In the early 1990’s a concrete block industry developed a new type of concrete masonry unit. The main changes are the cells geometry modification and the block walls thickness reduction. Laboratory tests attested that components mechanical strength and other block properties were consistent with Brazilian Standards. But the block wasn’t able to be used as structural masonry unit due to the reduction in block walls thickness.

At this time São Paulo Municipality launched a wide urban redevelopment project and the replacement of “favelas” for multi storey buildings, named Cingapura Project. It was based on 5 storey (Ground Floor + 4 Storey) structural masonry buildings. It was implemented in several city regions totaling over 130,000 m² (square meters) constructed area and around 3,000 apartments.

To evaluate the new block technical viability as structural masonry element for the Cingapura Project, the company conducted a large test program. Compression tests were performed on grouted (reinforced) and hollow walls, diagonal tension tests on hollow walls, and flexion-compression tests on hollow walls. As complement, site load tests were conducted on buildings made of structural masonry block and also on the new block, providing satisfactory structural performance. The study's findings were sufficient to allow the new block use in São Paulo housing project and many other similar typology buildings. The product was a success and is being widely used until nowadays.

This paper presents the new block development stages and presents the study results summaries. During the period of Brazilian Standard NBR 6136/2006 revision, the study comprehensiveness and strength supported the development of a new class of concrete hollow blocks (Blocks "C" class).

Keywords: CMU manufacturer, innovation, masonry, special masonry unit

INTRODUCTION

Structural masonry with concrete blocks was used in Brazil began around the year 1968. In 1982 were published the first Brazilian concrete blocks standards with the growing use in Brazilian buildings. The initial standards to specify blocks were: NBR 6136 - Simple concrete blocks for loadbearing masonry, and NBR 7173 - Simple concrete blocks for non loadbearing masonry. Under these standards, concrete blocks were divided according to their use, into two kinds of blocks: blocks with loadbearing functional and blocks without loadbearing function. NBR 6136 specified the acceptance conditions for loadbearing concrete
blocks such as: definitions, dimensions, strength classes, water absorption, drying shrinkage, calculation methodology of the characteristic strength (Fbk) and sampling.

In early 1990s a large housing project started in São Paulo and focused on building construction to replace slums. Called Project Cingapura or PROVER – Programa de Verticalização de Favelas (Slums Verticalization Program), intended to meet at the end of 72 months half a million people, or 92000 families through the construction of 30000 apartments and improvements to 62000 urban families, reaching a total of 243 slums clusters (ABIKO, PEREIRA, 2002).

The Cingapura Project focused on building 43m² standard apartments in 5 floors buildings (ground floor + 4 floors) without elevator. In the vast buildings majority was used Structural Masonry Building System. Figure 1 shows an aerial view of a completely re-urbanized slum by Cingapura Project.

![Image of Cingapura Project](image)

*Figure 1: The Cingapura Project (Construbase, 2011)*

At the same time, focusing on costs optimization in structural masonry for low-rise buildings (up to 6 floors), a major concrete blocks manufacturer from São Paulo, Brazil, developed a new block type with thinner walls. With the wall thickness exception (less than specified in the standards), the new block attended all other features specified in the standards (IURKY et al. 2008).

In order to attest the possible use of the new blocks in the housing projects, the manufacturer hired a renowned Brazilian research institute (IPT - Technological Research Institute of São Paulo) to conduct an extensive research study. Two programs were performed: one for the study of the new block model and another concerning building load tests (IPT 1999, IPT, 1996).
OLD NBR 6136

Since its initial publication in 1982, the old NBR 6136 passed through minor revisions, only in 2006 this standard was completely restructured. It is shown below old standard NBR 6136 main aspects.

- **Dimensions:** The old NBR 6136 standard dimensions are listed in Table 1. The manufacturing tolerances specified are ± 2 mm for width and ± 3 mm for height and length.

<table>
<thead>
<tr>
<th>Nominal dimensions (cm)</th>
<th>Designation</th>
<th>Standardized dimensions (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Width</td>
</tr>
<tr>
<td>20 x 20 x 40</td>
<td>M-20</td>
<td>190</td>
</tr>
<tr>
<td>20 x 20 x 20</td>
<td></td>
<td>190</td>
</tr>
<tr>
<td>15 x 20 x 40</td>
<td>M-15</td>
<td>140</td>
</tr>
<tr>
<td>15 x 20 x 20</td>
<td></td>
<td>140</td>
</tr>
</tbody>
</table>

- **Minimum blocks wall thickness:** as shown in Table 2, for blocks with 15 cm modular dimensions, the longitudinal and transverse walls minimum thickness is 25 mm. For blocks with 20 cm modular dimensions, minimum thickness for longitudinal walls is 32 mm and for transverse walls is 25 mm.

<table>
<thead>
<tr>
<th>Designation</th>
<th>Longitudinal walls(^{(A)}) (mm)</th>
<th>Transverse walls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Walls(^{(A)}) (mm)</td>
</tr>
<tr>
<td>M-15</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>M-20</td>
<td>32</td>
<td>25</td>
</tr>
</tbody>
</table>

\(^{(A)}\) Average measure of the three walls taken at the narrowest point.

\(^{(B)}\) Sum of thicknesses of all transverse walls to blocks (in mm), divided by the nominal block length (in meters).

- **Minimum compressive strength requirements:** according to Table 3, there are two resistance classes in NBR 6136/1994 according to the blocks uses: Class AE, for use above and below grade. Class BE, for limited use above the ground. The compressive strength was calculated according to equation 1 below:

\[
f_{b,k,est} = 2 \frac{f_{b1} + f_{b2} + \ldots + f_{bm-1}}{m - 1} - f_{bm}
\] (1)
**Table 3: Minimum compressive strength \( f_{bk} \) (NBR 6136 / 1994)**

<table>
<thead>
<tr>
<th>Compressive strength class (MPa)</th>
<th>Classe AE ( f_{bk} ) ((A))</th>
<th>Classe BE ( f_{bk} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,5</td>
<td>4,5</td>
<td>4,5</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
</tbody>
</table>

- **Absorption**: the standard minimum absorption required is 10%.
- **Drying shrinkage**: should be less than or equal to 0,065%.

**THE NEW BLOCK MODEL**

In order to offer a more competitive product (with more slender walls) and compressive strength sufficient for low-rise buildings construction, the new model was developed based on a block for non-loadbearing masonry wall, produced exclusively for a São Paulo major builder (Iurky et al. 2008). The new model development took advantage of the high quality blocks produced with special cement (ARI CP-V type) in Besser machines model Vibrapac v3.12 and steam-cured.

The major development was in refining the block geometry. Numerous geometric configurations were tried and after many tests the “four corbels” geometry have been selected. There was also the need to adapt the mixing ratio.

Figure 2 illustrates the geometric block differences in structural (loadbearing) blocks produced according to old NBR 6136 and the new model developed.

**Figure 2: Geometric differences between the two types of blocks**
In 1996, to facilitate building construction solutions for Cingapura Project, a large Brazilian construction company conducted (in partnership with IPT – “Instituto de Pesquisas Tecnológicas”) a comparative study in the building site to verify the new model block performance by performing a load test in real use conditions. The results showed that, for the studied design typology, no significant parameter differences were found.

This was the first step toward legitimizing the use of the new block for loadbearing walls in low-rise buildings. However, besides the Brazilian standard then in effect does not regulate the new model use, there was little knowledge about the properties and strength correlations between units, prisms and walls. It was necessary an extensive study, conducted in 1999, exploring the main resistant characteristics of loadbearing walls using the new block. Both studies and their main conclusions are summarized below.

**COMPARATIVE STUDY 1 – BLOCKS, WALLS AND PRISMS LABORATORY TESTS**

Below are the main aspects and conclusions of laboratory experiments with the new block model contained in the IPT Technical Report (1999).

Besides the new block model characterization tests, for comparison, studies were also conducted with structural (loadbearing) blocks (with geometry as the NBR-6136 prevailing at the time, with 25mm walls).

For a comparative study only one compressive strength class was used to the standard structure block and three classes of compressive strength for testing the new model: medium, lower and higher than medium. We were also used in the walls and prisms construction, bed laying mortar and grout with three compressive strength levels: medium, lower and higher than medium. Were conducted the following tests:

- **Characterization tests on applied materials:**
  - Block, prism, mortar and grout compression samples, hollow and fulfilled with grout.
  - Determination of moisture, water absorption, drying shrinkage and net and gross areas of concrete blocks.

- **Structural tests:**
  - Simple compression of filled walls, with medium blocks, average laying mortar and poor, medium and rich grout fill.
  - Simple compression of hollow walls, with poor, medium and rich blocks and medium laying mortar.
  - Hollow walls flexure-compression, with standardized medium blocks study, medium laying mortar and three eccentricity load values.
  - Hollow walls diagonal tension, with standard medium block study, and poor (low cement/sand ratio), medium (medium cement/sand ratio) and rich mortars (high cement/sand ratio)
  - Impact of soft-bodied in hollow walls with standardized medium blocks study and medium mortar.
Figure 3 illustrates some tests situations.

![Image of tests situations]

**Figure 3: Walls resistance tests (IPT, 1999)**

- **a) Simple compression**
- **b) flexure-compression**
- **c) diagonal tension**

The main conclusions for the studied topics are:

- **Physical blocks characteristics:** the standard blocks and new blocks studied had satisfactory moisture, water absorption and drying shrinkage results according to NBR6136.

- **Block compressive strength:**
  - The ranges variation of blocks resistance (average in gross area) analyzed were superimposed - equal to 6.9, 7.4 and 8.0 MPa for the poor, medium and rich mix ratio, respectively.
  - The resistance ranges variation of hollow prisms analyzed also were superposed - average net area equal to 10.3, 10.1 and 12.5 MPa respectively, for poor, medium and rich block and medium mortar (9.6 MPa).
  - Hollow prisms resistance with the new studied blocks - for the medium mix ratio (10.1 MPa), and considering the poor, medium and rich mix ratio (11.0 MPa) - were relatively close to the hollow prisms resistance with medium standard structural blocks (9.6 MPa). Therefore, it is reasonable to comparatively analyze the average results from tests of walls built with these blocks.
  - The resistances relationships (wall / prism / block) experimentally determined for hollow and grouted walls showed compatible behavior for the new studied blocks and for the standard loadbearing blocks (also compatible with the predicted value by the project norm - equal to 0.70).
  - The forecast for the longitudinal elastic modulus, related to hollow walls with new studied blocks (E = 1.000 x hollow wall compression resistance in the net area) presented to be valid showing difference of about 7% compared to the values experimentally determined.
• **Hollow walls flexure-compression tests:**
  - The developed break tension states, obtained for walls constructed with standard loadbearing blocks and new studied medium blocks, considering the eccentricities imposed, were close to each other.

• **Impact tests:**
  - The impact tests (soft-body) results, for walls with medium mortar and standard loadbearing blocks, and new studied medium blocks, despite the difficulty of defining wall’s rupture criteria, were considered similar among themselves.

• **Hollow walls diagonal tension tests:**
  - Walls constructed with standard loadbearing blocks and new studied medium blocks, with medium mortar, showed diagonal tension resistances (NBR-14321/99) very close together (0.89 MPa and 0.91 MPa, respectively).
  - The walls with new studied medium block showed increasing diagonal tension resistance with the mortar strength, considered with poor, medium and rich mix ratios (0.82 MPa, 0.91 MPa, 0.96 MPa, respectively).
  - Transverse elastic modulus values to walls with new studied blocks and the standard medium loadbearing blocks, with medium mortar, were relatively close to each other, with difference of about 12%.
  - The diagonal tension rupture modes were basically similar for all walls tested with standard loadbearing blocks and new studied blocks, i.e., wall cut following the compressed diagonal (Figure 4 c).

In short, the IPT work (1999) concludes that the results series for the two block types (standard loadbearing blocks and new studied blocks) indicate behaviors consistent and compatible. It wasn’t observed in any of the tests results, for both blocks types, indications of altered behavior.

**COMPARATIVE STUDY 2 – BUILDING LOAD TESTS**

Below its related aspects and conclusions of load tests carried out in buildings constructed with the new model blocks included in the IPT Technical Report (IPT, 1996).

The objective of the study is to make a comparative experimental evaluation through load test of the one of the most demanded structural wall performance in a building, considering the loading resulting from residential typology. Tests were conducted in October 1996 in two Cingapura Housing Project of São Paulo City Hall, located in Vila Nilo, São Paulo-SP.

The two buildings were identical, consisting of 5 floors, with a ground floor and 4 (1st to 4th floor) stories, with structure made of masonry loadbearing walls with 15cm nominal width blocks. One building was fully constructed with structural concrete blocks (internal walls with 25mm thicknesses, according to Brazilian standard) and the other with the new developed blocks (walls with thicknesses less than 25mm).

The living room floors were made of prefabricated prestressed concrete panels, with 1.0m width and supported toward the room’s lower interspace. All floors panels from the fourth upper floors were loaded, corresponding to the living room floor of the next apartments.
The loading was applied with water, setting up in each room a pool with 1.64 m x 3.24 m and 0.55 m height. As maximum load was considered incidental load to residential buildings (forseen in the Brazilian standard of 150 Kgf/cm² plus a coefficient of 1.4, i.e. equal to 210 Kgf/cm²). This load, applied in four steps was implemented in order, from 1st to 4th floor and unloading was applied by following the loading reverse steps. Figure 4 illustrates the floor plan showing the tested wall and pools location in the apartments.

As main conclusions the IPT study highlights:

- In the visual inspection performed after the load tests, none structural abnormalities resulting from applied loads were found,
- In the visual inspection, the results of the two load tests carried out in two buildings, constructed with modular concrete blocks of different thicknesses on the longitudinal and transverse walls, showed satisfactory structural performance, tested in the two buildings, for the loading levels achieved.

Figure 4: Wall loading in load test scheme (IPT, 1996)
NEW NBR 6136 DEVELOPMENT AND PUBLICATION

With the results of these investigations, builders and designers began to be aware of the results and the new block model began to be used.

Around 2002, a commission was established to review and update the technical standards related to concrete blocks. Among the reviewed issues was placed on the agenda the new block model formalization, based on conducted studies. In 2006, after a lot of debates, was published the new NBR 6136 - Hollow elements for masonry.

For this paper purposes, one of the most important changes was the unification of the two standards (of loadbearing blocks and nonloadbearing blocks) in a single standard, dividing the blocks into four resistance classes (Table 4):
- Class "A": use in loadbearing walls, above and below ground level, with at least 6 MPa characteristic strength (formerly Class AE);
- Class "B": use in loadbearing walls, limited use above the ground level, with minimum of 4 MPa characteristic strength (formerly Class BE);
- Class "D": use only as a partition or facade nonloadbearing element, with at least 2 MPa characteristic strength;
- Class "C": new resistance class creation, incorporating the acquired knowledge by refine and use of the new block model in addition to the performed studies and researches (briefly described here)

Table 4: Summary Table – Concrete blocks specification (NBR 6136 / 2006)

<table>
<thead>
<tr>
<th>Class</th>
<th>Compressive strength (fbk)</th>
<th>Module (cm)</th>
<th>Wall thicknesses (mm)</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>≥ 6 MPa</td>
<td>M 15 / 20</td>
<td>25 / 32</td>
<td>Loadbearing: below and above ground level</td>
</tr>
<tr>
<td>B</td>
<td>≥ 4 MPa</td>
<td>M 15 / 20</td>
<td>25 / 32</td>
<td>Loadbearing: above ground level</td>
</tr>
<tr>
<td>C</td>
<td>≥ 3 MPa</td>
<td>M 10 / 12,5 / 15 / 20</td>
<td>18</td>
<td>Loadbearing: 10 (storey house), 12.5 (2 floors house), 15 and 20 cm (higher buildings)</td>
</tr>
<tr>
<td>D</td>
<td>≥ 2 MPa</td>
<td>M 7,5 / 10 / 12,5 / 15 / 20</td>
<td>15</td>
<td>Nonloadbearing: “Apparent” or “to be coated”</td>
</tr>
</tbody>
</table>

- Dimensional tolerance: ± 2 mm to thickness and ± 2 mm to height and length;
- Absorption: ≤ 10%;
- Drying shrinkage: ≤ 0.065%.

SUMMARY AND CONCLUSIONS

This paper presents technological development conducted by construction companies as a way to achieve sustainable competitive advantages. Often, it is the innovation that should “push” the market and boost the technological level of a segment or sector. The work clearly demonstrates the industry mobilization (manufacturers, consumers, research entities) in face of an innovation launched by a manufacturer (until be nationally standardized and recognized).
The work also demonstrates that a new product launch to the market should be done with great responsibility and, in most cases, requires high initial investments that may not have a return in the short time. Investment in the development of new products required great intellectual effort.

Also during the new block development the absence of a standard based on building performance with clear criteria and requirements complicated the new product acceptance in the market by the lack of comparative parameters. Today there’s a building performance standard to be published in March 2012.

Nowadays, the new block is sold as "product line" and it’s a great commercial success of the company, who is constantly seeking in innovation to be a national reference and stay in the market as the leader.

ACKNOWLEDGEMENTS
IPT – Instituto de Pesquisas Tecnológicas de São Paulo – Engº Roberto Katumi Nakaguma, Engº Carlos Eduardo de Siqueira Tango

REFERENCES


