DEVELOPMENT OF MASONRY MODULAR PRODUCTION SYSTEM

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To increase concrete hollow blocks sales and profits, in the early 2000’s, a major Brazilian concrete block industry launched in São Paulo market a Modular Production System for Nonloadbearing Walls (for partition and exterior walls). This technological innovation was named SVM (Modular Masonry System, in portuguese) and combine all materials supply (blocks, mortar and accessories), construction workforce, tools and equipments supply, and design technical support. As differentials, the company ensure structural performance, building schedule (agreed on contract), and the agreed price. This new product was developed in São Paulo, Brazil, where the industry conducted more than 50 building sites with this technology.

This paper presents all aspects related to product development (quality manuals, project guidelines, building procedures, product development and R&D), management and commercial development (partnership shaping, commercial strategies, management procedures), plus the building phases and control (workforce training, technological selection, management and production control).

Conclusions demonstrate the economic viability of this building system. The system also raised awareness about concrete block masonry performance characteristics, since it remains largely used as nonloadbearing walls.

Keywords: CMU manufacturer, masonry innovation, construction system

1 INTRODUCTION

Building construction in Brazil, including nonloadbearing masonry, is divided among several agents:

- the compatibility project (when designed), is done by a specialized company;
- planning and monitoring services are responsibility of the construction site engineer (from the construction company);
- materials purchase (blocks, mortar, other materials) is done by the construction company supply department, and are acquired from different manufacturers;
the construction is responsibility of a workforce contractor, which doesn’t have trained technical staff;

- tools and equipment supply is carried out by both the contractor and the construction company.

In this configuration the responsibilities are diluted and, if there are problems, those responsible are rarely identified. Invariably the construction company assumes the errors and pay for schedule increases, costs and quality loss. Below are the main problems faced by construction companies:

- **Excessive materials loss**: there are no links between those who purchase (construction company) and those who use (contractor);

- **Low workforce productivity**: planning is responsibility of the construction company, who constantly adjusts the pace of the various services; often the material handling is the responsibility of the construction company, and if this service is badly managed can cause delays; lack of planning: large amount of reworks because of interference with other services (shafts, coatings, etc.);

- **Low quality execution**: there is little commitment of the contractor to quality; deficient training; high labor turnover; informality; and impunity since the contractor errors reflect in cost and schedule increases for the construction company.

The brazilian building and construction sector went through a crisis in the 1990s. Figure 1 illustrates numbers related to formal jobs in the construction sector, registered in São Paulo metropolitan area. Notice that since 1997 there was a significant decrease in the generation of formal jobs in civil construction. The market remained retracted until 2005, when the civil construction sector began a strong growth process.

![Figure 1: Number of formal employees in construction industry in São Paulo Metropolitan Area (SEADE, 2011)](image)

Given the late 1990’s recession shown above, the concrete blocks market leader in the São Paulo metropolitan area was facing difficulties:

- Retracted market (offer greater than demand);
- Commoditized product (fixed price, market regulated);
- High quality and priced product;
- Can’t make the market "realize" the product value;
- Direct competition with low-quality blocks;
- Culture of using ceramic blocks for nonloadbearing walls;
• Construction companies with high incidence problems in quality and performance of nonloadbearing walls.

Within this outlook, the company developed the innovative production system by aggregating the materials and services supply, taking responsibility and ensuring all aspects related to the masonry produced. The system was marketed as a closed package deal through a single agent and with guarantees provided by contract. Figure 2 illustrates the system structure. To the complete project development, the company built a partnership with Professor Fernando Henrique Sabbatini.

![Masonry Modular Production System Diagram](image)

**Figure 2: SVM (Sistema de Vedação Modular) Structuration**

The innovation in question was called SVM (Sistema de Vedação Modular - Modular Masonry System), and its development allowed great value increase to the product and ensured high profit levels.

The purpose of this paper is to present the characteristics of this Modular Masonry System, list the stage of development, and illustrate the works where this technological innovation was used.

### 2 MODULAR MASONRY SYSTEM (SVM)

The SVM component materials are:
- Concrete nonloadbearing hollow blocks (CMU);
- Mortars for block laying;
- Reinforced mortar precast elements;
- Accessories (hardware cloth / metal lath /wire mesh for wall tie, anchors, pins and fixation elements);
- General materials (sand, cement, lime, additives, etc.).

To ensure the masonry quality the first step was to establish a series of strategic partnerships with all suppliers, ensuring favorable business conditions. The partnership agreements also included development and adaptation stages for new products, materials or technologies.
2.1 BLOCKS (A NEW FAMILY)
Within the idea of production rationalization and the search for the maximization of masonry performance, the SVM starting point was the development of a new family of unities. The system offers solutions that cover every situation with construction details that use a reduced number of components, simplifying the construction.

Following the international trend and respecting the modular coordination standard, the basic module is 10cm. The reference unit has the nominal dimensions of 30cm (length) and 20cm (height). In width, the nominal dimensions are 10cm, 15cm and 20cm.

To maintain the continuity of holes in the rows superposition, and once the units have three holes, the "tie" between rows is done in \( \frac{1}{3} \) and \( \frac{2}{3} \), i.e., every 10cm or 20cm. Because of it, there are 20cm (\( \frac{2}{3} \)) and 10cm (\( \frac{1}{3} \)) components. The 10cm (\( \frac{1}{3} \)) element was designed to be sub-divisible, generating 5cm (\( \frac{1}{6} \)) elements that allow horizontal modular adjustments.

Additionally, to permit vertical modular adjustments were developed two modular channel / blocks of 5cm and 10cm in height, both with 30cm nominal length. The Figure 3 shows the components family for a 15cm nominal thickness.

![Figure 3: 15cm Thickness Components Family](image)

In order to increase productivity, and because they are focused on nonloadbearing masonry, most walls are built without mortar on the vertical joints. For this reason, the typical vertical joint was defined as 0.3cm and the entire (\( \frac{3}{3} \)) piece real length was defined as 29.7cm (and the fractions as 9.7cm and 19.7cm). Figure 4 illustrates the components family, a typical block and a tie between walls example.

![Figure 4: a) 10cm Thickness Family b) Real dimensions of the entire block (15cm Family), c) 1/3 wall tie design example](image)
2.2 MORTARS
Mortars for laying blocks have critical influence on the functional performance of walls. They must have features such as workability, water retention capacity, adequate strength, deformability, adhesion and durability. Choosing the best mortar depends not only on the type and composition, but also on the characteristics of masonry units (Sabatini, 1986).

Because it is a rationalized production system, it was defined that the mortars would be industrialized, bagged and prepared near the application site. This choice was based on the necessity of characteristics standardization, minimizing control on the receipt, storage easiness, transportation speed and flexibility. For this purpose, a partnership was established with a major mortar supplier industry. To determine the optimal mortar ratio (for bag application technique, the mortar should be carefully measured to ensure enough plasticity), was signed an agreement with São Paulo University where were special mortars were developed.

In order to verify mortar quality parameters before each work start, adhesion tests (prisms) were performed, as shown in Figure 5.

![Figure 5: Adhesion tests performed before construction works](image)

2.3 PRECAST AND OTHER MATERIALS
The SVM also has a precast components family made of reinforced mortar, used as lintels, bond beams and frames, compatible with the walls modulation. To ensure product quality all precast are made in an industry with controlled ratio, molding and curing. Just as the blocks and mortars, these materials are delivered palletized directly in the building sites. The Figure 6 illustrates the dimensions of a modular adjustment element for doors, a precast window frame, a window lintel (or bond beam) before and after application.

![Figure 6: SVM Precast elements example](image)
2.4 WORKFORCE
A key aspect of the SVM success is related to the high quality and productivity of the workforce.

Because it´s a development of a rationalized system dependent on the workforce productivity, for the first works a partnership contract was signed with just one general contractor. As the system became consolidated, the company expanded its workforce partners. The company also set up its own bricklayer’s team to ensure process mastery, reduce labor turnover and enable the continuous technological development and improvement. Figure 7 illustrates mortar application with the mortar bag. The use of this tool can allow the increase of productivity and the reduction of mortar consumption.

Figure 7: Utilization of technique of mortar bag application

The quality and productivity of the workforce services were based on extensive and continuous training programs, conducted both in the company and in the building sites at different times (hiring, early works, part-time).

2.5 TOOLS AND EQUIPMENTS
In partnership with leading manufacturers, tools and equipment were developed to ensure high productivity in the masonry construction. All development was directed to the blocks geometry (30 cm and 3 holes). Block carts, mortar buggies, mortar tubs power mixers, rules, levels, squares, poles, etc. Figure 8 illustrates some of the equipment used.

Figure 8: Tools and equipments: special block carts, mortar buggies and horizontal axis mixer.
2.6 PRODUCTION AND COMPATIBILIZATION PROJECT
The design stage is very important to ensure construction productivity and quality. It is the production design that conducts the production, predicting any interference and avoiding work improvisations.

The project is also a basis for planning the building work (number of deliveries, materials movements; blocks per floor, etc.). The building work supervision is also done based on the project. The formal receipt of the finished services is based on the project and construction tolerances.

A complete project manual was prepared with all the system technical characteristics to allow any designer to make the masonry production project.

2.7 PLANNING AND MANAGEMENT
For each work carried out an overall construction planning of the building is done. This planning serves as basis for price formation and contract formulation. The building management is done based on the planning.

Each work has a resident technical and a full time workforce commissioner, responsible for ensuring the work’s progress and quality. For each group of four works, there is a qualified technician, who manages strategically the services.

The construction work is based on clear execution procedures (procedures are a contract item). The controls are clear and objective, done by building technical workers. Figure 9 illustrates the design and construction manuals.

3 Warranties
By providing a complete package and concentrating materials and services on a single agent, the company is able to ensure several aspects such as:

- **COST:** The system is sold by package (extended price). This means the price is fixed for the contractor. Any production failure or variation is the contractor sole...
responsibility. For example: in case of blocks breaking or mortar excessive consumption, costs are entirely funded by the contracted company;

- **DEADLINE**: Along with construction work prices, deadlines, terms and conditions, the construction schedule (prepared by both parts) is a contract part. The contracted part ensures compliance with the implementation period laid down, and delays are subject to penalty. On the other hand, changes in building work conditions (such as modifications, equipment breakdown and the non liberation of work fronts) can result in penalties for the contracting company;

- **QUALITY**: The quality parameters (quality of applied materials and finished services – construction tolerances) are contractually formalized. All services must be performed according to the project (and planning) and in case of non-compliance or execution failure all costs are under the responsibility of the contracted part;

- **PERFORMANCE**: Although it is a system focused on nonloadbearing masonry, SVM is sold with a structural performance guarantee (in Brazil, in early 1990, there were lots of pathologies related to masonry caused by unexpected endeavors originated in excessive deformation in reinforced concrete structures). Any problem related to masonry, as fissures, is covered by formal guarantee.

**4 DEVELOPMENT STAGES**

Because it’s an important technological innovation, SVM was developed in 3 macro-steps until its marketing consolidation on a commercial scale. Initially the whole technology development was performed, defining the materials, design criteria, construction work procedures and partnerships build up. In total there were 44 months of development (including 27 construction works) until the marketing of the first works on a commercial scale. A summary of the development stages is shown below:

**Early technological development** - this step was carried out in 7 months and included the initial development for the first constructions on a prototype scale.

- Development of family blocks;
- Development of the project manual;
- Partnerships with material suppliers;
- University agreement;
- Construction work procedures development;
- Partnerships with workforce contractors.

**Implementation of 3 prototype scale constructions** - this step took 13 months and included the building of three sites with different characteristics, in order to verify hypothesis achieved during the development. Although being a prototype, all works had "real" budgets and schedules and the performance guarantees have also been applied.

- Consolidation of the projects manual and construction procedures
- Verification of tolerances and quality criteria
• Partnerships with new material suppliers
• Development of their own workforce teams
• Early development of budget and marketing procedures
• Training development
• Sales team (SVM sales) training and development

Implementation of 24 pilot scale constructions - this was a consolidation stage and last 28 months. It included the accomplishment of 24 works where the final adjustments in the construction parameters were made, in addition to the commercial aspects development (SVM sale have different characteristics from products sales).
  • Consolidation of the project manual and construction procedures;
  • Consolidation of partnerships (suppliers and workforce contractors);
  • Consolidation of commercial procedures and team.

5 CONSTRUCTIONS / RESULTS
During the development phase constructions were done through contracts with different builders. Figure 10 illustrates some works done in the prototype-pilot phase.
The works had distinct characteristics: size of the construction site, differences in vertical transport (cranes, lift), construction scale, number of towers per building site, schedules. These characteristics were important to define the budget, planning and construction parameters.

6 FINAL CONSIDERATIONS

SVM established itself as an important technological innovation in the market for nonloadbearing walls in São Paulo. The performance, cost and time guarantee meet the desire of the builders, that recognized the value added to the services package offered and allowed sales increase and ensure the company's profit margin during a crisis time.

The concrete blocks superior performance also allowed to significantly improve the market share of the concrete block in constructions with nonloadbearing masonry, increasing sales in a market once dominated by ceramic nonloadbearing blocks.

It’s possible to say that SVM established a technological benchmark (for materials and techniques), disseminating good practices that were "copied" and ended up being incorporated in the building technology currently in use.

Nowadays, because of industry operational characteristics and market changes (strong increase of loadbearing masonry sales), the commercialization of SVM was temporarily suspended.

7 REFERENCES


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