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The Structural Masonry Construction Method

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----------***ABSTRACT***----------
Structural masonry is an optimized construction system in which the masonry itself has a structural function. Another feature of the system is the use of concrete blocks and modular ceramic blocks in order to streamline the construction process, reduce material and labour costs, and generate greater speed in execution. For all these reasons, structural masonry has been widely used in the Brazilian civil construction industry, encompassing buildings of all finishing standards. Thus, short deadlines and reduced costs are the laws that guide today's construction projects. To meet these important requirements, new techniques are being deployed and improved. This paper will address a development in structural masonry based on a residential construction profile showing how a construction system can have both positive and negative impacts on a job in relation to costs and deadlines. Beyond presenting the main concepts of this construction method, this paper also includes a case study showing how this method could be implemented and the main issues that arise at a construction site due to bad service and/or poor inspection.

KEYWORDS;-*Structural Masonry; Concrete Block; Grout; Construction method*

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I. INTRODUCTION

Structural masonry has been reported as an economically favourable construction solution within the principles of sustainable civil construction [1-3]. With the emergence of new companies in the construction industry and the competition between them, the question of the efficiency of a construction method has become an issue faced by most companies, who want to guarantee their profit, their customers, and their permanence in the market. The optimization of manpower and materials are the key parameters to guarantee efficiency in construction, while building in accordance with quality standards, high productivity, reduced costs, and reduced deadlines are the main goals for companies aiming for recognition in the civil construction market [4-8].

The structural masonry construction method has been used by large companies that want to guarantee these aspects of their business. Profit and short term are characteristics of a successful construction.

Structural masonry, made from concrete or ceramic block, is gradually replacing many other construction methods that would be undertaken with conventional reinforced concrete, resulting in greater economy, practicality and quality. The use of this construction system has been widely used not just in low-income housing, but also frequently in medium- and high-standard buildings in which the number of floors per building increases considerably [4, 9-11].

The development of synthetic materials, such as iron and cement, as well as the improvement of suspension devices and construction equipment, have radically transformed construction techniques [2, 9, 10, 12-14]. After the development of a high-strength cement (Portland), obtained through a strong calcination temperature, the transition from lime technology to concrete brought great advances in construction [12, 15-17]. The strength qualities of concrete were further increased with the use of metallicreinforcement, first with iron and then with steel, thus becoming the ubiquitous reinforced concrete [7, 18].

Nowadays in the United States, England, Germany and other countries, structural masonry has reached levels of calculation, execution, and control similar to those applied in steel and concrete structures, constituting an economic and competitive optimized system, versatile and easy to industrialize, based on the small dimensions of the basic modular component typically employed (block) [10, 19, 20]. Structural masonry has many possible uses: single-family or multi-family dwellings, commercial residential buildings, hotels, schools, hospitals, industrial sheds, retaining walls, reservoirs (including circular ones), swimming pools, silos, etc. Within the structural masonry construction method, non-reinforced concrete masonry seems to be one of the most promising options in the market, both for the ease of supply of materials and for the economy that this construction system provides [21].

Structural masonry is indicated for construction of buildings up to 12 floors. In these cases, walls with thicknesses of 14 cm are used and the resistance of the blocks is given by the ratio of 1 MPa multiplied by the number of floors above the considered level [8].

In this work, both the positive and negative impacts of structural masonry will be studied in relation to costs and deadlines. The main concepts of this construction method will also be discussed showing step-by-step how this method is executed and the main problems that can arise at a construction site due to poor service or inspection. A practical case study was done directly at a construction site (seven buildings of six floors each) where all blocks were made of structural masonry.

II. BACKGROUND

Materials used in structural masonry

The components used in the execution of structural masonry buildings are washed sand, gravel, blocks, reinforcement (constructed or from calculation), mortar, and grout, all of which are needed in correct proportions in order to reach the characteristic strength (fck) needed to accurately calculate the material content for the structure to be built [22, 23].

Foundation

The choice of type of foundation made to receive a masonry structure depends on several factors, such as type of soil in which the construction will be made and the geography of the site, but the primary factor to keep in mind is that structural masonry has a rigid structure and no failure or cracking can occur, as these structural defects would condemn the whole construction [24, 25].

One recommended type of direct foundation is the slab foundation that consists of a type of surface that distributes the entire load of the building evenly on the ground. It is a continuous solid slab of concrete that is an advantageous alternative, in many cases, to a deep foundation. Depending on the characteristics and scale of the project, a slab foundation can be made from reinforced concrete, fibre-reinforced concrete, or prestressed concrete [1, 2, 12, 14].

A slab foundation of reinforced concrete involves reinforced concrete slabs in direct contact with the ground and placed to receive the loads from the pillars and walls and distribute them uniformly on the ground. It is the most suitable foundation for structural masonry. A direct shoe foundation can be used for permissible soil pressures of not less than 100 kPa and gaps between structural walls not exceeding 5 m.

There are also cases of foundations made of cyclic concrete, in which stones of sizes ranging between 10 and 30 cm are used in the foundation together with concrete.

Other types of foundations may also be used depending on the soil where the building will be built. Indirect foundations may be used, such as deep foundations with precast reinforced concrete perforated to 15 to 20 m deep with crowns of stakes and crown blocks interconnected by straps [26]. Fig. 1 illustrates the type of foundation used in a structural masonry project.

Figure 1. Foundation using precast concrete stakes.

Steps in the structural masonry cycle

Concrete/masonry cycleStructural masonry always begins with concreting the first slab, which is usually made in a different way from the other slabs of the building because it must support the entire load of the building. This first slab usually contains some pillars, strategically arranged through calculations, to drain the loads in the best possible way to the foundation. In this construction, there are some beams that together with the pillars are responsible for shoring the structure as a whole [8, 27, 28].

The next slabs to be built in structural masonry are auto-supported, i.e., executed without pillars and beams in a similar way to those executed in a conventional concrete structure. The use of conventional reinforced concrete considerably increases the wood consumption of construction, consequently increasing

material costs; moreover, a slab executed in structural masonry is thinner than a conventional concrete structure not having pillars or beams and being directly supported by itself.

Forms

Forms for civil construction and its subsystems have definitions and requirements specified in standards, which must be followed in order to avoid problems [9, 22, 25, 27].

Forms can be considered as the set of components whose main functions are to mould, contain, and sustain fresh concrete until it has sufficient strength to support itself and to provide the required texture for the concrete surface [29]. Fig. 2 shows the forms used in civil construction.

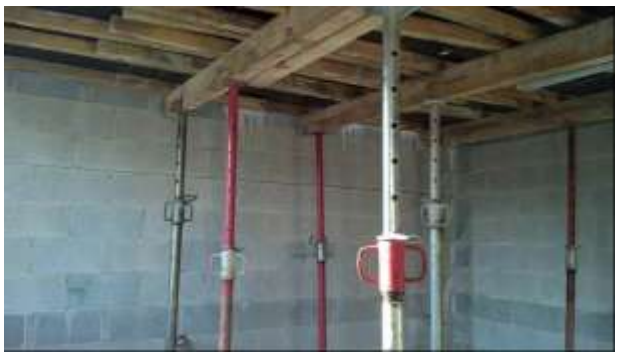

Figure 2. Image of the forms used in a structural masonry construction.

Frame and installations

Before levelling of the form to fit the correct ceiling height estimated in the design, a variety of other installations are implemented: electrical installations (Fig. 3), including lightning rods that should not be concreted inside the block, hydraulic installations, air conditioning drains and boxes for future passage of slabs, gas installations embedded in the slab, and execution of the frame, with the positive and negative mesh of the slab hardware. After levelling, spacers are placed between the iron mesh and the floor so that the frame does not touch the wood and is not concreted incorrectly [30, 31].

Figure 3. Image of the execution of the negative and positive frames as well as the electrical installation in the slab.

Grout points and specific details

Grout is a specific type of concrete, indicated to fill empty spaces of blocks and channels, in order to increase the compressive strength of the masonry without increasing the resistance of the block or mortar. Even in the case of armed masonry, the grout also has the function of integrating the armour with the masonry [32, 33].

Grout is composed of the same materials used to produce conventional concrete, but it differs from concrete in terms of the size of the aggregate, which is smaller and thinner, and in the water/cement ratio, which is higher [16, 34].

Grout requires the use of Portland cements. In specific cases, lime may be added to the mixture to decrease its stiffness, from 0 to 1/10 of the cement volume. Hence, these mixtures require less cement, allowing the grout to achieve a higher compressive strength and less shrinkage during the hardening of cement [16, 33, 34].

There are some specific points for concreting a slab that will receive structural masonry that should be addressed. One peculiarity of this system is that after making the conferences of forms, frames and installations,

but before concreting, the grout points (Fig. 4a) need to be given careful attention. It is necessary that these points follow exactly what was determined in the project, because each grout point plays the role of a pillar in the structure, so each point needs to be placed in the same position, slab after slab, with no deviation. Furthermore, attention should be paid to the placement of the iron axes (Fig. 4b) that will be pulled after the concreting to indicate where the marking and location of the blocks will be made. Finally, tubes must be put in the peripheries so that they can be removed after the concreting and placed in the same location for the peripheral protection of the perimeter masonry.

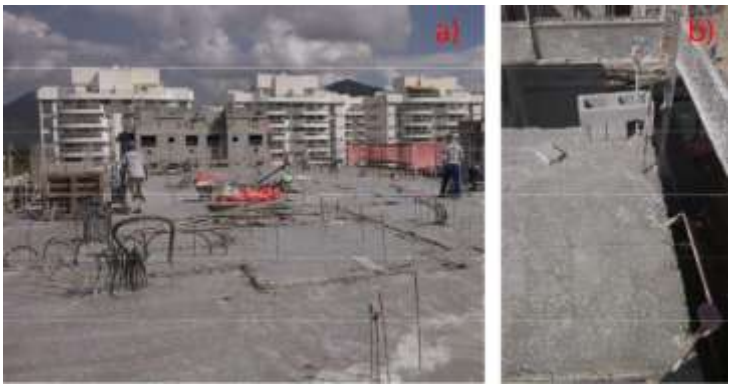

Figure 4. a) Image of grout points and b) iron axes placed before concreting to indicate the marking and location of the blocks.

Concreting

Concreting occurs with machined concrete. It can be launched by stationary pump, boom pump, or crane. It is executed by a specialized team that works with the necessary equipment to execute the service correctly, using a batten, vibrator, hoe, spatula, leveller, etc. After concreting, the concrete is cured. Then, after the wet curing finishes, a process that usually takes seven days, marking of the blocks begins [1, 22, 24, 28].

Elevation of masonry

The next step is the first elevation of the masonry up to a height of 1.2 m or a 6-block row (Fig. 5a), where the last row does not use a common block, but a gutter. In this phase, it is always necessary to be aware of the plumb of the walls and whether they are being raised correctly, so that there are no future problems due to walls being out of plumb. It is also important to ensure their flatness and that they are raised square. Their level is also important to ensure that pagination is not affected in the last few rows.

In the sixth row gutter, an iron is placed horizontally to be grouted (Fig. 5b). At the same time, an electrician can also pass guides through the masonry, leaving the electrical points explicitly called for in the installation project. Grouting is first done just for the vertical points. Then, the gutters are grouted (Fig. 5c).

The same process is repeated when the second masonry elevation is executed (Fig. 5d). The only thing that differs from the first elevation is the attention to the window spans that appear in that elevation, and these must conform to the pagination design of the walls. It is also important to pay attention to the staples or wire meshes placed in the armed and unarmed masonry, Figs. 5e and 5f, respectively.

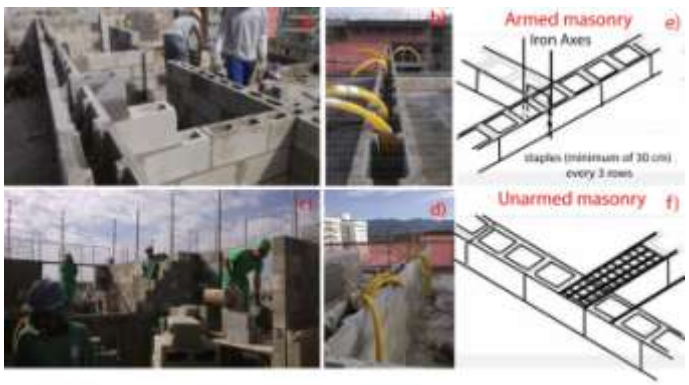

Figure 5. a) First elevation of masonry, b) Sixth row gutter picture where an iron is placed horizontally to be grouted, c) Second elevation of masonry d) Sixth row gutter picture showing the electrical guide and gutter frame, ready to be grouted, e) armed masonry illustration and f) unarmed masonry illustration, both showing in detail the connecting armature of the outer walls.

III. CASE STUDY OF STRUTURAL MANSONY

The case study was performed on a construction site planned to be a standard condominium residence of seven buildings of six floors each, plus a swimming pool, sports court, parking, and pavement. The construction method used for this project was structural masonry. The choice of this construction system was based on its cost reduction and ease of work delivery (Fig. 6a).

The type of foundation used in the project was nailed pre-moulded stakes. All of the planned buildings are similar except block 1, which has its first slab made of conventional reinforced concrete with beams and pillars and sealing walls due to the existence of shops on the ground floor. The development consists of 322 medium standard apartment units.

The complete structural masonry cycle covered approximately nine days, with the form and frame made in three days, the concreting taking place on the fourth day, the marking of the first row of blocks on the fifth day, the completion of the elevation of the masonry on the sixth through eighth days, and the grouting of the gutter of the 13rd row on the ninth day. This shows that the process is relatively fast compared to conventional reinforced concrete process which takes between fifteen and thirty days. However, the time frame depends on the weather conditions, as the phase of elevation of the masonry must cease when it rains.

Fig. 6b shows a detailed step-by-step execution of the masonry cycle. The structural masonry steps are as follows:

- first elevation of the masonry of the first half of the pilotis joint (Fig. 6b, picture 1);
- first elevation of the second half of the pilotis together with grouting of the gutter in the 6th row of blocks placed in the first path (Fig. 6b, picture 2);
- grouting of the gutter in the second path and beginning of the second masonry elevation in the first path (Fig. 6b, picture 3);
- second masonry elevation of the second path and beginning of the mounting of struts, falsework, and floor of the first path (Fig. 6b, picture 4);
- grouting of the first path (already assembled) and mounting of the struts, falsework, floor and positive and negative armature of the second path, as well as execute electrical installations (Fig. 6b, picture 5);
- grouting of the second path and mounting of the structures already cited in the first path and beginning of the frame of the first path (Fig. 6b, picture 6);
- finalization of the frame of the second path and beginning of the concreting of the pavement (Fig. 6b, pictures 7 and 8);

Figure 6. a) Plant of the construction site where structural masonry technique was applied and investigated in the case study, b) step-by-step execution cycle of structural masonry.

As mentioned earlier, the entire process takes around nine days to be finalized without interferences in the execution

IV. CONCLUSION

Structural masonry stands out more and more among building systems because it is a simple and efficient method. Construction companies have discovered in structural masonry a very competitive alternative for the construction of buildings, mainly when compared to the traditional system of reinforced concrete. Interest in the construction system of structural masonry has focused on the great advantages found, especially economic ones.

It is important to mention that the design of the construction system to be adopted in an enterprise depends on its individual circumstances, a feasibility study to guarantee quality work, and the performance of the construction

company and its recognition in the market. For a successful enterprise, five key factors must be rigorously managed: projects, technology, supplies, production organization, and manpower. An enterprise where these items are respected will potentially be an optimized work with less loss of materials and labour and, consequently, lower costs.

It can be observed from this study that, in comparison to the conventional structural method, based in reinforced concrete, the structural masonry system with concrete and ceramic block presents a great deal of efficiency in relation to the reduction of costs, reduction of material waste at the construction site, improved quality of service, and a decrease in delivery times.

In the face of so many benefits, the limitations should also be mentioned. These include the impossibility of building high-rise buildings, the lack of architectural flexibility, and the need for masonry components with adequate characteristics.

Before deciding on this construction method, one must carefully analyse the market in which it will be implemented. For example, professionals who state that this method is not preferred with respect to safety still exist. However, even though it has its drawbacks, it has been concluded that the construction method of structural masonry has its strong and relevant points in relation to cost and time, and should be studied further by the great construction companies as a very effective method and a market booster.

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