The performance of non-conventional building system applied to low-income houses

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Abstract: The Brazilian public housing has taken significant steps towards mitigation of problems with the housing shortage, given the high number of new homes for those without a place to live. However, in the midst of this evolution in the volume of execution of social interest housing, it highlights the strong need for seeking integration from the design stage to the usage-maintenance stage. In João Pessoa-PB, 600 Housing Social Interest (HIS) were found in Mangabeira neighborhood, built partially with non-conventional construction technology. Realizing the lack of technical assistance by those responsible for the project, this study aimed to identify how these low income houses have behaved at the moment of use and operation. The results obtained indicated that in spite of being under development building maintenance actions, the problems were detected during the first year of use and hence proved to be extended with the time. It was evident that the problems originated from not following the requirements of technical standards and incompatibility of various steps in the construction process.

Introduction

Many are the ways that lead a building undergoing degradation. Also, many are the causal variables that contribute to the deterioration of buildings. Some of these variables are: a) insufficient specification about choice of building materials to be used; b) disobedience to the requirements of technical standards; c) preliminary design understudied; d) lack of supervision and monitoring during building execution; e) no maintenance during use. If these variables are in compatibility, so performance of the building as planned will provide. However, if incompatibility of these steps is present, then performance requirements cannot be achieved. And this issue takes greater proportion if we consider public construction in Brazil, where high volume of housing units are built without planning, design or use-maintenance. It should be emphasized the concern to reduce the housing deficit in Brazil. However, construction of new housing is not the only solution. Plans for the maintenance initiatives of existing buildings are also important, in order to make them comply with their planned performances, seeking the fulfillment of project useful life.

Based on previous informations about the performance behavior of some buildings, such as the existence of problems and their respective occurrence in time, new buildings can be built without the errors undertaken previously.

So, this work aims at presenting a study of the performance of sixty eighth Social Interest Housing (SIH) that were built with non-conventional building system in the city of João Pessoa-PB-Brazil. These houses were designed and built by the state government, during the years 1999 and 2002. The non-conventional building system means the use of reinforced concrete plates and precast reinforced concrete columns to constitute the walls and structure of the house.
Literature Review

According to NBR 5674[1], buildings are designed to meet the needs of its users for many years. During this period, the performance of the building shall correspond satisfactorily, with appropriate conditions of use and facing well environmental agents of aggression as well as the activities arising from the use of the property.

The buildings, have no way to be held endlessly, i.e. there is always a natural wear [2]. The same line of reasoning is followed by Antoniazzi and Soares [3]. These authors associate the lifecycle of the building to variables, such as: durability of the materials, exposure conditions, occurrence of periodic maintenance and its use. Also, Andrade and Costa and Silva [4] emphasize that the deterioration of buildings is closely related to time and conditions of use. Therefore, the absence of compatibility of all these variables will provoke the appearance of pathologies, resulting in loss of performance and shortened life planned for the property.

Steen cited by Andrade [5] ensures the need first to identify the pathological manifestations that are occurring more frequently and later to seek how these problems have evolved in time.

Pathology usually arises from external manifestations. To Helene [6] this fact can be considered as a tool that helps to identify the nature, origin and mechanisms of the phenomena involved. Based on this principle, the author secures that there are diseases that manifest themselves more often because of actions or initiatives that should have been taken in any of the steps of construction (design, execution and / or use) and that perhaps have been neglected due to failure to consider the relevance of the subject.

The origin of pathology in buildings may be associated with the steps project, execution and use. According to Andrade and Silva [7], the causes of deterioration of a building may come from mechanical actions, physical, chemical and biological. However, these actions they can both occur in isolation as happening simultaneously.

Silva [8] presents some points that need to be worked out to minimize the occurrences of pathologies in buildings: "(i) Investment in civil construction technology and better qualification of the workers; (ii) change in mind of consumers, demanding more quality and durability warranty of the products purchased, focusing also on the importance of preventive maintenance; (iii) awareness of designers (specification of concrete with adequate workability, design of structural parts with reinforcement densities that allow for efficient concrete work); (iv) responsability of builders concerning care in the transport stage, launch and consolidation, ensuring the coating thickness of reinforcements and (v) awareness of users of all economic levels about the importance of ensuring the useful life of structure spending as little as possible in restoration work and rehabilitation (generally companies working with structural recovery are called only when the damage reaches the high degree of degradation)".

To ensure the life of a building, attention is essential to the monitoring of their performance to verify that you have met the minimum requirements acceptable. Performance can be defined as "behavior in use of a building and its systems" according to NBR 15575 [9]. Therefore, the monitoring of performance of a building can measure its useful life and identify whether it will possibly be fulfilled.

Regarding the life of a building, the performance standard [9] makes a statement which makes a distinction between useful life and the project useful life. According to For the standard, useful life is the "period of time in which a building and / or their systems lend the activities for which they were designed and built considering the frequency and correct execution of maintenance procedures". On the other hand, the project useful life is defined as the "period of time for which a system is designed to meet the performance requirements of this standard, considering the compliance with the requirements of the applicable standards, the state of knowledge at the time of design and assuming compliance with the frequency and correct execution of maintenance procedures".

In this paper, the variable performance is evaluated focusing on Social Interest Housing built with non-conventional building system in the city of Joao Pessoa. The goal is to identify whether these buildings are responding satisfactorily to the intended use, and ensure that minimum acceptable levels of performance were achieved.
Description of the Houses Studied
Precast buildings with 33.40 m² of floor space, ceiling height of 2.40 m; composed of: living room, one bedroom, one bathroom, one kitchen, one terrace, one laundry area, coverage with ceramic tiles over mixed wood structure (no battens), apparent hydraulic and electrical systems, plumbing and painting with lime for walls and oil for frames.

Methodology
Sixty eight housing units (HU) built with non-conventional building system as profile I reinforced concrete columns (see Table 01 and Fig. 1) and reinforced concrete panels (see Table 02 and Fig. 2) had their performance evaluated. Other components of the house were also evaluated. These HU were built following the sequence shown below:
- 17 units delivered in 1996;
- 17 units delivered in 1998;
- 17 units delivered in 2000;
- 17 units delivered in 2002.

Table 01 - Description of columns, height and quantities

<table>
<thead>
<tr>
<th>Pillars</th>
<th>Height</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>3.20</td>
<td>3</td>
</tr>
<tr>
<td>C2</td>
<td>3.40</td>
<td>4</td>
</tr>
<tr>
<td>C3</td>
<td>3.00</td>
<td>14</td>
</tr>
<tr>
<td>C4</td>
<td>3.60</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>27</strong></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1 – Cross-section and reinforcement of columns

Table 02 - Description of panels: labels, dimensions and quantities.

<table>
<thead>
<tr>
<th>Slabs</th>
<th>Dimensions (m)</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>0.76 x 0.30</td>
<td>18</td>
</tr>
<tr>
<td>L2</td>
<td>1.59 x 0.60</td>
<td>46</td>
</tr>
<tr>
<td>L3</td>
<td>0.76 x 0.60</td>
<td>40</td>
</tr>
<tr>
<td>L4</td>
<td>0.76 x 0.30 x 0.50</td>
<td>1</td>
</tr>
<tr>
<td>L5</td>
<td>1.59 x 0.40</td>
<td>2</td>
</tr>
<tr>
<td>L6</td>
<td>1.59 x 0.60 x 0.20</td>
<td>2</td>
</tr>
<tr>
<td>L7</td>
<td>0.76 x 0.60 x 0.40</td>
<td>2</td>
</tr>
<tr>
<td>L8</td>
<td>0.76 x 0.70</td>
<td>1</td>
</tr>
<tr>
<td>L9</td>
<td>1.59 x 0.30</td>
<td>14</td>
</tr>
<tr>
<td>L10</td>
<td>0.76 x 0.90</td>
<td>1</td>
</tr>
<tr>
<td>L11</td>
<td>0.76 x 0.40 x 0.90</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>128</strong></td>
<td></td>
</tr>
</tbody>
</table>

1 These are precast columns, with reinforcement steel CA 60, diameter 4.2 mm, stirrups placed every 20 cm and concrete in dosage 1: 3: 3 (cement:sand:gravel 19).
Two documents were prepared to obtain information about the conditions of the components of the building. Firstly, a checklist with all the elements that constitute the building in order to seek and identify, through observation, the problems of each item. Secondly, an interview form, where the aim was to identify the instant of occurrence of the problems, through the answers of the owners of the houses.

With the data collected, the SPSS statistical software (Statistical Package for Social Sciences) was used in order to analyze and rank the current state of the components of the building, besides the identification in time of the appearance of the problem during use.

Results and Discussions

Based on the results achieved with the assistance of the interview forms, it was possible to identify the average of how many HU presented deficiency in its components in the year in which they were handed over to their respective owners. It was also possible to know about the behavior of building in the first four years of use.

Before starting the study of performance of the buildings, informations about the maintenance of houses were sought in order to verify if lack of maintenance has been one factor that influenced the deterioration process of the evaluated components. For this, the average of houses that had maintenance in its components during use was carried out at the years of their deliveries (1996, 1998, 2000 and 2002).

**Fig. 1** - Percentage of buildings that have undergone maintenance initiative

**Fig. 2** - Percentage of buildings that presented problems in the year of delivery according to the components evaluated
By analyzing Fig. 2 we can see that the structure presented problems at each year of delivery. The houses built in 1996 and 1998 only had problems on structures. Houses delivered in 2000 were those that appeared more problems.

Fig. 3 shows the average percentage of buildings that had problems with respect to each building component in the delivery year and also in the first four years of use.

It shows that the elements that showed problems, both in the year of delivery (about 32.35% of houses) as well as during the first four years of use (about 91.18% of houses) were the structural columns. On the other hand, the panels appear as the second place, when evaluated in the delivery year, presenting deficiencies in 14.71% of houses. In the assessment of four years of use, the component that is highlighted at second place is the floor that reaches the percentage of 30.8% of houses. The component that did not show any deficiency in the year of delivery was the covering.

Furthermore, for the four years of use, the percentage of buildings that presented problems in this component was the lowest, with 4.41% of the investigated properties.

From Fig. 4, it was possible to observe a relationship between maintenance actions and the occurrence of problems. By analyzing the results, we can see that in spite of the maintenance initiatives carried out in houses, the problems happened, mainly on structure and floor elements. Even with the maintenance actions, the percentages of pathology cases surpass even the maintainability initiatives. In structure, for example, it can be seen that there was a large number of buildings that have undergone maintenance. Indeed structure was the element which was more likely to care by the owners of the property. But even despite this maintenance investment, the structure still stands out as the element that showed problems, given that 91% of the properties investigated had problems in that item. As the structure, the floor behave similarly, while 40% of houses were maintainable on their floors, 49% of them had problems.
From the analysis of the data showed in Fig. 5 we can raise two arguments: (i) the maintainable actions among the components that make up the buildings seem to occur without intent, given the numbers are quite diversified with each other, suggesting improvisation and not schedule of these services. Another finding concerns (ii) the fighting against the appearance of problems by maintenance initiatives. Except to the structure and floor, all other components of the house showed percentages of problems down the percentages of houses that have undergone maintenance, suggesting that maintaining presented satisfactory results in the manifestation of a problem in most constituent items of the house.

With the forms answered, current situation of the buildings was also possible to be classified. It was possible then to characterize the building in: critical condition, regular state or minimal state. Building Inspection Standard [10] was used to sort the houses within these features.
Regarding the classification of the components of the house about their current state it can be said that the components of the studied houses are classified mostly as the minimum degree of risk. Regarding the critical degree of risk classification, electrical installations and covering are the worst. The only element that did not present critical level in that data collection was the toilet.

**Conclusion**

This study aimed to gather information regarding the performance of some houses components constructed from non-conventional building system. The following conclusions can be highlighted: Maintenance actions, developed by the owners, benefited most homeowners because, in general, the percentage of houses with problems was below the number which showed abnormality during a period of use of four years. However, this fact alone does not apply to the structure and floor components. The structure was the component that most benefited from maintenance actions, however, was the most that expressed underperforming. The floor in turn, got in pathology percentages above 10% of houses that have undergone maintenance initiatives.

It was also observed that some properties have already been delivered to the prospective owners with the presence of problems and there were other houses in the first year of use where the components presented problems. Among the property of the constituent elements that stood out in the manifestation of problems it was to structures (columns), because this was the component that presented negative results in both the house delivery year as well as during the first four years of use.

Covered was the only component that did not present any problem upon delivery of the house and also there was no manifestation of pathology in this building element during the first year of use. However, during the four-year use of the house it was observed that the indoor presented problems, but being smaller percentage compared to all house elements and in view of the low occurrence of maintenance initiatives in the use step, the component line covering presents itself today, as the second placed in the critical risk classification.

Another relevant point is identified in the results that compared the four years of use of the property in relation to the year of delivery to the owners, it was found that the elements that had the highest percentage of problems were related to homes delivered in the year 2000; which are: firstly the structures, the second floor, then the Frames and the sealing plates occupying the fourth position.
The HU’s delivered in 2000 also showed problems in higher percentage in the Hydraulic facilities, sanitary facilities.

Another important fact still concerns the absence of the real estate behavior analysis in previous periods, that is, it is concluded that the demands were not observed regarding the occurrence of the problems encountered in the real estate delivered in 1996 and 1998 for decisions to be taken improvements in projects that would be executed in 2000 and 2002, where it is identified that failures kept happening and if we take as reference the structures, for example, it is clear that the percentage was higher in the year that is already held in hands high rates HU’s of underperforming.

References