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Fire safety evaluation: an alternative method for Brazilian buildings

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ABSTRACT

With the aim of proposing the legalization of the use of buildings that are subject to restrictions on fire safety legislation in Pernambuco, Brazil, some performance-based fire assessment methods have been described and one of them has been chosen to be applied to two buildings in the city of Recife, proving its effectiveness. As a result, safe and viable solutions have been envisaged, given the restriction for buildings considered as historical heritage or constructed based on previous laws that have been updated. Gretener's method, if implemented, could become an interesting practice, insofar as it proposes some low cost and safealternatives without structural interventions, given the international verification of its effectiveness.

Keywords: fire; safety; legislation; methods.

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Avaliação de segurança contra incêndio: método alternativo aplicado a edificações brasileiras

RESUMO

No intuito de legalizar o uso de edificações que se encontram com restrições de adequações à legislação de segurança contra incêndio vigente em Pernambuco, Brasil, alguns métodos de avaliação de incêndio com base no desempenho são descritos e escolhido um deles para ser aplicado a duas edificações, na cidade de Recife, atestando sua eficácia. Como resultados foram vislumbradas soluções seguras e viáveis, haja vista a restrição em edificações tombadas pelo patrimônio histórico ou construídas baseadas em leis anteriores que foram atualizadas. O Método de Gretener, se aplicado, poderá se tornar uma prática interessante à medida que propõe algumas alternativas sem intervenções estruturais e de baixos custos, e seguras, tendo em vista a comprovação internacional de sua eficácia.

Palavras chave: legislação; segurança; incêndio; métodos.

Evaluación de seguridad contra incendio: método alternativo aplicado a edificaciones brasileña

RESUMEN

Con el objetivo de proponer la legalización del uso de edificaciones que se encuentran con restricciones en cuanto a la legislación de seguridad contra incendio vigente en Pernambuco, Brasil, algunos métodos de evaluación de incendio basados en el desempeño han sido descritos, y se ha elegido uno de ellos para ser aplicado a dos edificaciones en la ciudad de Recife, comprobando su eficacia. Como resultado se han vislumbrado soluciones seguras y viables, dada la restricción para edificaciones consideradas como patrimonio histórico o construídas con base en leyes anteriores que han sido actualizadas. El método de Gretener, de ser aplicado, podría volverse una práctica interesante, en la medida en que proponga algunas alternativas sin intervenciones estructurales, de bajo costo y seguras, dada la comprobación internacional de su eficacia.

Palabras-clave: seguridad; incendio; legislación; métodos.

1. INTRODUCTION

Despite the concern with the preservation of life and of the existing patrimony in a building, another factor has been added to the search for fire safety on the part of the owners of constructions: the achievement of the Technical Visits of the Fire Department, required in Pernambuco, Brazil, by Law 11,186 of December 22, 1994. In addition to safeguarding condominium trustees or legal persons responsible for civil or criminal liability buildings, in the event that buildings are affected by fires, and from these disastrous consequences, this document has become paramount for the granting of insurance, participation in tenders and release of housing permits from the counties. It begins by stating that in Pernambuco, according to data from the Center of Technical Activities of the Metropolitan Region of Recife, an organ belonging to the State Military Fire Brigade that carries out inspection of fire safety systems until November 2015, approximately 3000 requests are pending for some type of impediment. The reasons for this are diverse: financial difficulties for the adaptation to the current legislation, the duration of the work for the fulfillment of the exigencies, or structural impossibility to respect what is prescribed in the Fire and Panic Security Code for the State of Pernambuco.

Noting that each federal unit of Brazil has its own legislation on the subject, in addition to international regulation, it is perceived that there are several ways to establish security criteria or to give faith that a certain building has the minimum conditions to provide security to its users, And of prevention to the occurrence of fires. In this article some of these methods will be approached, and one chosen in particular to be compared with the evaluation methodology of Pernambuco.

In Brazil, fire safety regulations and laws are very recent. The absence of large fires that resulted in considerable losses, either in the patrimony or the number of lives lost, had never allowed, at least until the beginning of the decade of the 70s, a relevant discussion on the subject in the country. It was from the occurrence of major accidents that the authorities and researchers have begun to perceive the importance of the implementation of more rigorous rules for constructions, with the intention of making them safer for their inhabitants (SEITO et al., 2008, ZAGO et al., 2015). Following this trend, after the tragic fire in Santa Maria County, in Rio Grande do Sul, resulting in 242 fatalities, the discussion for the implementation of a national fire safety code, implemented by the National Secretary of Public Safety at the moment, Luiz Fernando Corrêa, who decided to set up a Working Group, on June 14, 2015, with the objective of elaborating studies and presenting a draft bill that deals with fire safety and panic throughout the national territory, has gained strength, according to the additional data observed in Table 1, where external impact translates into the number of deaths in fires in Brazil.

Table 1. Records of the biggest fires in Brazil

Building	Date	Consequences
Gran Circus Norte-Americano (RJ)	December 15, 1961	503 fatalities and about 1000 injured
Industria Volkswagen (SP)	December 18, 1970	01 fatal victim and total destruction of the factory
Edificio Andraus (SP)	February 24, 1972	16 fatalities and 336 injured
Edificio Joelma (SP)	February 1, 1974	16 fatalities and 336 injured
Tiendas Renner (RS)	1976	41 fatalities and 60 injured
Boate Kiss (RS)	January 27, 2013.	242 fatalities and 680 injured

Source: Seito *et a*l (2008) & Previdelli (2013)

Keeping in mind this incipient legislation, it is not difficult for fire control systems, represented by state fire brigades, to face the problems encountered in buildings constructed prior to these standards. Until 1970, in Pernambuco, there were no rules that would discipline the area, and the demands imposed were based on the county codes of work (SILVA, 2006 and 2015). Architectural concepts applied to the construction of stairs, ventilation and exhaust ventilation, emergency exits, in addition to the criteria of the fire-fighting system, such as hydrants, detection and alarm and automatic showers, for example, are quite different from what is practiced today.

2. BACKGROUND

For Tavares (2002), the demands imposed by the fire brigades on buildings are a consequence of the observation of the large fires, which resulted in the so-called prescriptive codes, standards that are used criteria such as built area, height of the (wether in meters or number of floors) and type of occupation (commercial, school, industrial) to prescribe what safety measures must be taken by the buildings.

It is known that the so-called "residual, remaining or reserved" legislative competence is reserved to the Member States, according to which it would be up to the entities to innovate the legal order by the issuance of normative acts infra constitutional. In this way, the Constituion prescribes that public security constitutes "the duty of the State, the right and responsibility of all," being "exercised for the preservation of public order and the safety of persons and property." Among the organs mentioned in its art. 144, is found in subsection V, "military police and military fire brigades" (BRAZIL, 1988).

As a result of this legal system, a mixture of fire safety codices is perceived in Brazil (CORRÊA, et al, 2015). Although some of them are similar in their criteria (sometimes even faithful copies of each other), highlighting the relevance of the rules of the Military Fire Brigade of São Paulo and the Brazilian Association of Technical Standards that serve as a basis for many of them, each state has its own rules to deal with the matter.

It is therefore concluded, in view of the diversity of existing regulations, that there is no single way of establishing safety criteria for buildings. Thus, the search for alternatives different from those required by Brazilian state laws to attest that a particular building is in a position to provide security for its occupants is the way to unlock the processes of obtaining the Technical Visits of the Fire Department in the control organs of Brazil.

In this perspective, so-called performance-based codices are implemented in some countries (such as Australia, Japan, England, New Zealand, Canada, among others), according to Tavares (2002). For Ono (2007), performance-based assessments allow for greater flexibility in project design, resulting in more cost-effective solutions to more specific fire safety issues. According to her, performance-based projects combine calculations and technical knowledge of the principles that govern that area of engineering.

Tavares (2002) states that performance-based codices allow objectives to be mapped and that multiple paths can be traversed, at the discretion of the professional responsible for evaluation, provided that security is achieved. Table 2 provides a comparative summary between prescriptive and performance-based codices, according to Tavares (2002).

In the face of the possibility and the observance of other means of fire risk verification, some methods of evaluation are studied, practiced and diffused in other countries. Bukowski (2006) warns that a career has been generated in the interest of investigating and applying methods of fire risk assessment with the intention of verifying how the performance of the buildings occurs in the face of the occurrence of fires, to the detriment of That prescribe the safety regulations, becoming alternatives to the simple use of the codes and regulations of the area.

Table 2. Advantages and disadvantages of prescriptive and performance-based codices.

	Prescriptive codices	Performance-based codices
Advantage	Direct interpretation with the established in the norms and codices, without the need of engineers with a more specific qualification in the area for the action.	Establishment of clearly defined safety objectives, leaving the engineers the methodology to achieve them; Flexibility for the introduction of innovative solutions that meet the performance criteria; Harmonization with international standards and codes; Safer projects with lower cost; Introduction of new technologies in the market.
Disadvantages	Lack of explanation for prescribed recommendations; Complex structure; Inability to promote safer projects with lower costs; Little flexible in terms of innovation, and therefore have only one way of ensuring fire safety.	Need for transition training due to change in application between codes; Difficulties in the validation of methodologies used in quantification.

Source: Tavares (2002).

For Watts and Hall (2002), risk assessment procedures are eminently studies aimed at knowledge of events that are not desirable, using the method of quantifying the probabilities of a given risk. Venezia (2011) emphasizes that the importance of risk assessment lies in the ability to identify situations that are determining for the perception and understanding of risk, and that are not clear or obvious.

The evacuation of people from buildings must be studied and evaluated in detail so that the risk is well proportioned (HANEA and ALE, 2009; KOBES, et al, 2010).

In Pernambuco, the Pernambuco Fire Brigade is legally allowed to deliberate on specific cases, complying with solutions that make feasible to the safety of buildings when certain entrants have been presented through technical resolutions issued by the corporation, at the request of the owners of the buildings or bodies concerned, or ex officio (PERNAMBUCO, 1997), which, despite the need for some of them, is not common practice.

Valentín (2009) says that the only valid parameter to determine which measures regarding fire safety must be applied is the exact knowledge of the degree of risk of that incident, either quantitatively or qualitatively. He also lists the objectives of the fire risk assessment, taking into account the real need to evaluate them. They are:

- the risk of a fire starting;
- the risk of fire spreading;
- the impact of a fire on a particular company;
- the human and material consequences for third parties, in case the fire exceeds the limits towards other properties;
- the human consequences of the company's own officials and their visitors.

Next, Table 3 presents some of the fire risk assessment methods that have been used in the fire risk assessment in the literature:

Table 3. Fire Risk Assessment Methods.

Method	Description
Fault Tree Analysis	Part of the analysis of the event of an unwanted event (fire, for example), looking for its causes and the chain of disaster.
Analysis of the event tree	Unlike the fault tree analysis method, it evaluates the damage consequences of the event.
FINE Method (Mathematical Assessment of Risk Control)	It is based on two procedures: one to calculate the relative intensity of each risk, and another to measure the economic costs derived from the preventive actions of these risks.
Intrinsic risk method	This model classifies fire hazards in buildings at three levels: low, medium and high. The classification is given according to the fire load existing according to its main occupation, measured in kilocalories per square meter.
Method of Edwin E. Smith	The method tries to establish a degree of danger for existing compartments and to present a model of a possible fire in the building under study, taking into account factors such as: flammability, heat and smoke emitted and rate of flame propagation.
Gretener method	It is the most comprehensive method for assessing fire hazards. Widely used to assess risks in large areas and facilities. It allows to quantitatively evaluate the risks through weights of factors taken into account in the occurrence of fires.

Source: Valentín (2009).

Silva and Coelho Filho (2007) point out that fire risk assessment methods are important tools for the verification of heritage and life safety. He states that the most widely used method for this is the Gretener Method, developed by the Swiss engineer Max Gretener in 1965, adopted three years later by the Swiss Fire Brigade as a tool to evaluate the means of fire protection in buildings.

The procedure developed by Gretener aims at determining a global safety factor through mathematical calculations, where some factors receive a certain score. The variants of this process are the most diverse, and many of them do not depend on the constructive characteristics of the buildings, which may represent some reduction of implantation costs, and non-invasive procedures from the structural point of view. Examples of these variants are: training of fire brigades, quality of the local fire brigade, distance from the building to the nearest fire brigade, the existence of constant surveillance in the building, among others. If this global factor is equal to or greater than 1.00, the building can be considered safe.

Following the Brazilian Rule 14432:00 from Brazilian Association of Technical Standards - requirements of resistance to fire of constructive elements of buildings - that allows the application of the Gretener appropriate to the brazilian reality, Silva and Coelho Filho (2007) have proposed some adaptations to the original method. An analytical form of calculation has been used, contrary to tabular values, with the intention of eliminating some existing discontinuities in obtaining certain values.

This method has been applied, albeit partially, in the fire departments of the states of São Paulo and Minas Gerais, as well as comparative studies to justify their implementation in the state of Santa Catarina (SOUZA; BACK, 2011). In the state of Paraná, the regulations allowing the use of Gretener's proposed assessment were enacted in July 2000 and amended in March of the following year. Among 24 items verified by the security code of the fire department of Paraná, 10 are based on the method in question (CARNEIRO; XAVIER, 2011).

3. MATERIALS AND METHODS

In order to subsidize the studies of the method and the alternatives of fire risk assessment, two buildings have been chosen in the city of Recife as a case study. One of them has its construction dated in the XVIII century, with occupation defined as a religious temple, and has restrictions for structural modifications, since it has been laid by the National Historical and Artistic Heritage Institute, the Madre de Deus´ Church. On the other hand, the building Santo Antônio, a building with commercial occupation, which has no restrictions due to having been knocked down, and also built before the implementation of Decree-Law 19.644 of March 13, 1997, which has instituted the Security Code Against Fire and Panic for the state of Pernambuco.

Data have been collected from the buildings for the use of the method, and also with the intention of framing them in the current legislation (built area, height, number of floors, among others). In addition, the fire safety conditions have been inspected for the presence of preventive equipment, as well as some questioning to those responsible for the buildings in order to verify the level of training of its occupants in what which refers to their preparation in case of fire.

To the extent that nonconformities with existing legislation and the impossibility of correcting them have been verified, either because they were built or because they were laid, the alternative method (Gretener) has been applied and, also, failure to obtain of the minimum satisfaction index, some modifications (without structural interventions) have been proposed as adequacy, with the intention of punctuating and, consequently, achieving the minimum safety index.

4. APPLICATION AND RESULTS

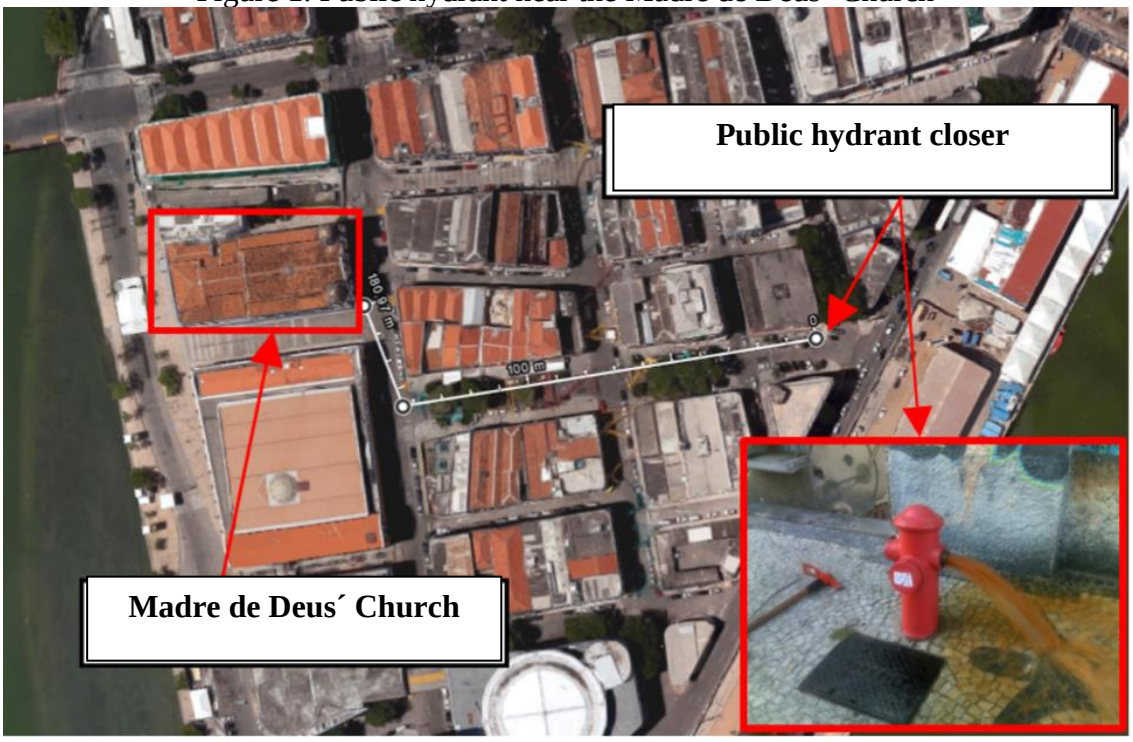
The Church of the Mother of God is classified, in the state of Pernambuco, by the occupation of Religious Temples. As such, and according to Fire and Panic Security Code for the State of Pernambuco, based on its built area, height and number of floors, it presents the explicit diagnosis of Table 4. It is perceived that the church does not meet the minimum requirements required by current legislation In the state of Pernambuco. The requirements to be fulfilled for the faithful observance of the specifications would require major structural interventions (such as changing the type of ladder and installing a reservoir for the hydrant system). With the intention of reducing or eliminating the need for such changes, without the overturning rules being injured, and even bringing benefits to surrounding buildings (such as the provision of public fire hydrants in the surrounding area, for example), it has been analyzed building through the Gretener fire risk assessment method.

Table 4. Diagnosis of preventive systems for the Madre de Deus´ Church according to Fire and Panic Security Code for the State Of Pernambuco.

Occupation	Religious Temples (“P” type)
Risk Class	A
Building´s Height (meters)	21.83
Area built (m^2)	1,041.83
Number of floors	3
Existing systems	Dry chemical fire extinguishers and common ladder
Required systems	Fire extinguishers dry chemical powder, water and carbon dioxide, emergency lighting system, emergency signaling, hydrant system, lightning protection system, and protected and cloistered stairs

Figures 1, 2 and 3 illustrate some of the factors that interfere with obtaining the overall safety factor according to Gretener.

Figure 1. Public hydrant near the Madre de Deus´ Church



Source: Google Earth (2015) y CBMPE (2015).

Figure 2. Openings for ventilation and exhaustivación of smoke of the Madre de Deus´ Church.

Figure 3. Absence of vertical compartmentalization within the Madre de Deus´ Church.
A – Balcony and windows inside the church; B – Ladder of the common type; C – Balcony inside the building itself.

After collecting data and weighting the values of the factors evaluated by the method, the following results presented in Table 5 were obtained:

Table 5. Diagnosis for the Madre de Deus´ Church, according to the Gretener Method.

Variants	Protective measure	Evaluated items	Calculated value
N	Normal protection measures	Fire extinguishers, hydrants, water adduction, fire brigade training.	0.218
S	Special protective measures	Modes of detection, transmission of alarm, quality of the fire department and exhaustion of smoke.	1.2
E	Constructive measures of protection	Fire resistance time of facade structures, concrete plant and divisions.	1.79
R	Fire risk	Fire load, combustibility, humidification and toxicity.	1.44
M	Mobility	Area and height of the behavior and service of occupancy of the building	1.216
I	Risk of fire activation	Building use type	0,85
		Global security factor	0.41

Once safety satisfaction, according to the method, is achieved when the overall factor is equal to or greater than 1.00, it is also verified that the Madre de Deus´ Church does not present the favorable indexes suggested by Gretener. To achieve them, some suggestions are proposed:

- ✓ Redimensioning and recharging of fire extinguishers and their correct dimensioning;
- ✓ Training of officials for fire situations;
- ✓ Night surveillance with access to the telephone;
- ✓ Installation of Wi-Fi detection system (without structural intervention);
- ✓ Gas extinguishing system;
- ✓ Redimensioning of the network of public hydrants (benefits to other buildings).

If the above solutions are applied (which would not require structural modifications to buildings laid down by National Historical and Artistic Heritage Institute, the overall safety factor will reach 0.97, which strictly does not meet the required minimum, although it is very close. However, the installation of building hydrants, without reservoirs, and pressurized by fire-fighting vehicles, would involve small structural alterations, with aerial plumbing installations, would raise the index to 2.11, exceeding the satisfactory minimum.

In contrast, the Santo Antônio building is classified in the Fire and Panic Security Code for the State of Pernambuco by the commercial occupation. Applying the same framing criteria of the previous building, we have the diagnosis according to the Fire and Panic Security Code for the State of Pernambuco method in Table 6:

Table 6. Diagnosis of preventive systems for the Santo Antônio Building, according to Fire and Panic Security Code for the State Of Pernambuco.

Occupation	Comercial (“E” type)
Risk Class	B
Building´s Height (meters)	Approx. 16 meters
Area built (m^2)	5,056.58
Number of floors	5
Existing systems	Dry chemical fire extinguishers, hydrants (without conditions) and common ladder.

Required systems	Fire extinguishers dry chemical powder, water and carbon dioxide, emergency lighting system, hydrant systems (maintained), locking stairs, fire detection and alarm system and automatic showers.

It is obvious that the commercial building does not fit into what Fire and Panic Security Code for the State Of Pernambuco demands. The demands for adequacy would also entail major structural changes. It happens that this building does not have impediments on the part of the organs of protection of the historical heritage, being then the Arabs for the adaptation only economic questions for the owner. Only one of them, the transformation of the existing open staircase into cloistered staircase becomes impossible because of the architecture of the building.
After data collection and weighting of the values of the factors evaluated by the method, the following results have been achieved at Table 7:

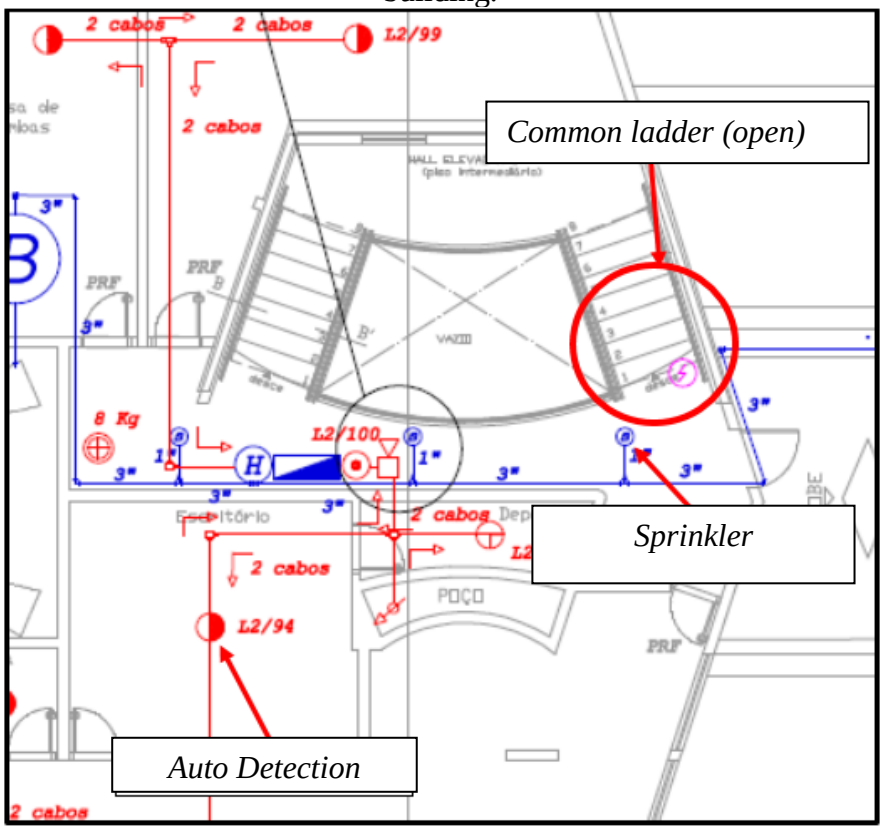
Table 7. Diagnosis for the Santo Antônio Building, according to the Gretener Method.

Variants	Protective measure	Evaluated items	Calculated value
N	Normal protection measures	Fire extinguishers, hydrants, water adduction, fire brigade training.	0.363
S	Special protective measures	Modes of detection, transmission of alarm, quality of the fire department and exhaustion of smoke.	1.785
E	Constructive measures of protection	Fire resistance time of facade structures, concrete plant and divisions.	1.576
R	Fire risk	Fire load, combustibility, humidification and toxicity.	1.49
M	Mobility	Area and height of the behavior and service of occupancy of the building	0.933
I	Risk of fire activation	Building use type	1,00
		Global security factor	0.95

As in the previous case, the minimum index has not been satisfied, despite having been very close, which could already be acceptable. However, as the building does not fit with the current state legislature, some corrections are suggested:

- ✓ Installation of intercommunicated detectors, according to model established by Fire and Panic Security Code for the State of Pernambuco;
- ✓ Installation of automatic showers.

Figure 4: Automatic detection forecast and automatic showers on the floors of the Santo Antônio. building.



With the installation of the automatic detection mode, the overall safety factor would increase from 0.95 to 1.38. Combined with the installation of automatic showers, it would go to 2.77. Installation of showers only, without the anticipation of the detection system would increase the factor up to 2.00.

5. DISCUSSION ON RESULTS

The choice of the method of Gretener is due to the fact that, in addition to reaching factors that are the basis for the formulation of other methods, it has palpable variants and easier to be adjusted in front of the conjuncture of the urban planning of Recife and the structure of the Local Fire Department. It adds to the practicality of its application, has seen the simple processing of information (presence or not of a certain system or activity in the building, distance to barracks and public hydrants) translated by numbers in a worksheet. The Gretener method not only quantifies the fire risks and thermal loads (such as the intrinsic method and/or FINE method, described in this article), data counted in any fire (evolution and speed of Edwin E. Smith, but adds to those The local characteristics (time-response depending on the traffic of each city, distribution of the network of public hydrants, quality of the Fire Department of the cities, preventive or not required by the legislation of each state), making it more adapted to the Reality found.

6. CONCLUSION

Faced with the problems that occur with non-compliance with the minimum safety requirements of buildings (impediment to the emission of Technical Visits of the Fire Department and lack of

safety for buildings), the need arises for new methods of obtaining indexes to be glimpsed Acceptable minimum as an alternative for the operation of these buildings, still obeying acceptable safety indices.

Brazilian state legislations have, with some exceptions, different evaluation parameters, which shows that there is not only one way of ensuring that a building is safe or not against fire occurrences. In Brazil and in European countries some methods are used, especially the one developed by the Swiss engineer Max Gretener.

Once two cases have been selected in Pernambuco, it has been verified that the application of this method can establish safety in buildings without major structural interventions being necessary, modifying or adjusting to factors that are, in fact, important in case of fire.

When the operations are applied by the method suggested in the study, it is evident that the minimum fire safety rate is obtained in the two exemplified practical cases. For the Madre de Deus´ Church, the proposed interventions did not give rise to any structural changes that, besides being economically interesting for the administrators of the building, are now feasible from the point of view of the conservation of the historical and The legal compliance corresponding to the fallen buildings. As for commercial construction, the installation of fire alarm detection equipment would already be sufficient to obtain the Gretener safety index. In this case, it should be noted that the simple application of the method (with the structure that already exists) shows that the building reaches the index, raising the debate about the effectiveness of the security measures implemented by the laws and the feasibility of using evaluations alternatives already practiced.

It is important to bear in mind that the study developed deals with a proposal for the feasibility of methods that have not been adopted by the Pernambuco Fire Department. Once the effectiveness and feasibility of its application have been certified, the Corporation may have practical and theoretical knowledge in order to propose changes in the current safety and fire law of panic.

These adjustments are important, since the potential use of buildings that do not comply with the prescriptive laws in force can not be ruled out, under penalty of damages to the economy of the cities, and non-use of the buildings for purposes that bring Development for society.

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