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Use of Forensic Engineering for Abandoned Building

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ABSTRACT

This descriptive study focused on the forensic investigation of abandoned Government Service Insurance System (GSIS) building in Manila. The post-fire investigation was conducted on structural elements in order to ascertain their in situ residual strengths and also to provide data for use in future assessment. Tests were conducted on beams, columns, and slabs in both the affected and the unaffected parts of the buildings. From the results, visual examination of the fire-affected buildings revealed that the steel corrosion and concrete deterioration are the major factors that affected the stability and integrity of structural members of the abandoned GSIS building in Manila. There was a notable reduction in the in situ strengths of the fire-affected structural members when compared with the unaffected members. However, the abandoned GSIS building is still in serviceable condition in terms of its structural members

***Keywords*:** Abandoned buildings, building codes, cracks, fracture, forensic investigation, gsis building

1. INTRODUCTION

The renewal of old buildings is important for many historians and architects as a means of revitalizing core city neighborhoods, conserving character defining elements of landmark buildings and improving their durability and seismic resilience. In parallel, efforts are being made to improve the energy efficiency of buildings to improve building energy affordability and lower greenhouse gas emissions. There is a perception that energy efficiency and heritage conservation are incompatible objectives, centered largely on the replacement of windows. As such, designated heritage buildings are often exempted from building energy codes and product standards (Ng, 2002).

A number of studies have looked at the way empty properties can generate and draw in crime. According to some civil engineers, abandoned buildings provide cover, concealment, and opportunities for motivated criminals (Spelman, 1993). Criminals are drawn to an abandoned property because it suits their needs and has few controls. An alley behind an empty warehouse, for example, is a perfect setting for a host of nefarious and illegal activity. As well as more serious criminal acts, it can encourage unwarranted vandalism or graffiti. There is always a lure for teenagers to break into abandoned buildings which can cause damage to the building and an increase in youth crime and underage drinking. There is also the danger of squatters occupying the building and metal thieves targeting the building to strip out things such as wiring and piping (Attar et al., 1993).

Abandoned buildings are rare in well-kept neighborhoods where demand for property is high, but it happens even in the nicest suburbs. When it does, the neighbors will be quite upset about the unusual blight.

In this situation, one possibility is that the abandoned building belongs to an estate, and the heirs cannot agree on a course of action, so nothing is done. Sometimes abandonment also occurs when the owner is a senior citizen and begins to suffer from dementia or Alzheimer's (Baba et al., 1989). The owner may be mentally ill or in jail. No doubt people will have their own unique reason behind a problem real estate parcel. That is why community development is such interesting work. Whether a person is in a great neighborhood or one past its prime, the techniques for taking action in the face of abandonment are similar; only the likelihood of success differs.

The most common method of dealing with abandoned building is through what is called code enforcement (Schilling, 1989). Most towns and nearly all cities have adopted some type of property maintenance code or law that lists standards that should not be violated. These also may regulate vacant lots. If the standard of the code that the town adopts are not met, it is a violation of a municipal ordinance. The problem with code enforcement in the abandoned building's situation is that the local government may well be unable to communicate successfully with the owner.

In the Philippines, more and more buildings are constructed especially in key cities in order to provide space for the growing industry of business, trade, and other services. Buildings are not just structures. These structures serve as a landmark and also show the progress of the place. Nowadays, there are already numerous abandoned buildings within Metro Manila. Within the municipality of Manila alone, several abandoned buildings can be sighted

Abandonment of property is the most striking indication of neighborhood decline. Large scale abandonment threatens the stability and undermines the value of investments made by property owners. Fire is intertwined with abandonment as both a cause and an undesired side effect. Abandonment usually signals the end of a buildings' productive life. Real estate market conditions, difficulty in obtaining financing for renovation or repair, withdrawal of fire insurance, and declining economic fortunes of tenants, all contribute to abandonment.

Structural failures are not just accidents. They are the result of the human error originating from oversight, carelessness ignorance or greed. The design of a structure must contain a support system with a clear line of load path and resist the applied loads to a stable resistive foundation (Garcia et al., 2007).

Most of the concrete-based infrastructure has now been in place for several decades. There is some feedback on technical performance at least in qualitative terms, but also at the level of deterioration in individual cases is dictated by a combination of factors in which design and construction issues are significant. The net effect can be a costly loss of function, or substantial unforeseen maintenance cost or both. However, the spectrum of obsolescence also enters the arena.

Many buildings and bridges have had to be upgraded or replaced because their functional needs have changed quite apart from any decrease in technical performance. In addition, the different components in individual artifacts (e.g. cladding in buildings; expansion joints on bridges) have been shown to have useful lives much less than those for the basic structure (O'Flaherty, 1993). These factors have led to a more conscious effort to manage and maintain the existing infrastructure and to introduce life-cycle cost techniques to evaluate alternative designs for new structures.

2. FORENSIC ENGINEERING

There is another forensics field through which scientists can determine the cause of failure in the bridge collapse, building destruction or on a small scale the failure of materials or components. It's forensic engineering.

Forensic investigation tends to start with a broad scope and becomes narrower as more information is discovered. Depending on the type of failure, forensic engineers may have more or less evidence to examine. In the case of a bridge collapse, the engineer may have to analyze anything from support beams to load capacity to foundation strength and everything in between. More specific issues, like a burst pipe, require a more focused approach. Independent testing labs may offer their own analyses of materials involved, such as pipe fittings, rubber, coatings, weld joints, glass and so on. Above all, it's important to maintain a systematic process that allows for the examination of all possible explanations and evidence.

In terms of today's forensic engineering, there is an increased emphasis on investigating the cause of failure of structures (Nangan ll, Ganiron Jr et al., 2017). This is because firms are being sued more frequently about allegedly defective products. There is also a continuing need for the investigation of fires, explosions, air and rail crashes and other important accidents or possible crimes. The past methods used use in early forensic engineering are the careful analysis of the service record of the component, the review of the loads carried, a record of temperatures suffered, analysis of the microstructure of the material used, and the assessment of witness evidence. This was usually carried out by optical microscopy, X-ray diffraction, and chemical analysis.

Today, all of these are still required but the task of the forensic engineer has been aided by the introduction of certain key concepts and methods including fracture mechanics, scanning electron microscopes, finite element analysis, computational fluid dynamics and impact dynamics

Fracture mechanics started with the ideas of Griffith in the 1920s on the fracture of brittle solids such as glass, where he suggested that the fracture strength was inversely proportional to the square root of the length of the largest crack (defect) present (Hillerborg et al., 1976). Later in the 1950s, when fracture had been seen in metals without prior plastic (permanent) deformation, the concepts of fracture mechanics were developed.

These can be expressed as KIc = QÛfv (a) where KIc is the fracture toughness, Q is the geometrical factor, related to crack and component geometry, and a is the length of the crack. By analysis of the crack size causing failure and the material, the stress causing the failure can be estimated and compared to the design stresses expected (Ganiron Jr, 2016).

Figure 1. Fracture mechanics of concrete

With the use of fracture mechanics as part of the design process, especially in high strength materials and in high integrity structures, such as aircraft and oil rigs, it is rare to see an instant fast fracture. More usually cracks grow by fatigue (repeated stresses) or stress-corrosion (synergy between tensile stress and corrodant). This crack growth is a function of stress intensity (KI = QÛv (a), where Û is the stress).

Commercial scanning electron microscopes became available in the mid-1960s (Yu et al., 1999). Their great advantages over conventional optical microscopy include an increased magnification from the 1-2000 of the optical microscope to 40-50000 and an increased depth of focus by a factor of about 300. It is possible to look at fracture surfaces, which will be too rough for optical examination, and examine polished sections at magnifications of more than 1000. The scanning electron microscope is shown in in Figure 2 operates by focussing a beam of electrons on a specimen, the point of focus is scanned line by line over the whole specimen. Images can be built up from the secondary electrons, the back-scattered electrons and the X-rays emitted. Within the last ten years, a more advanced type of SEM has become available, known as ESEM (E for environmental). Non-metallic samples do not need a conducting coating and may be examined up to atmospheric pressures, opening up great opportunities in both forensic science and engineering. The secondary electron image will produce an image of the shape of the object and therefore will be used on fracture surfaces and on polished and etched sections. The contrast from the back-scattered electrons is a function of atomic number, whilst the X-rays can be used as a detector of the elements present in the sample (EDAX analysis).

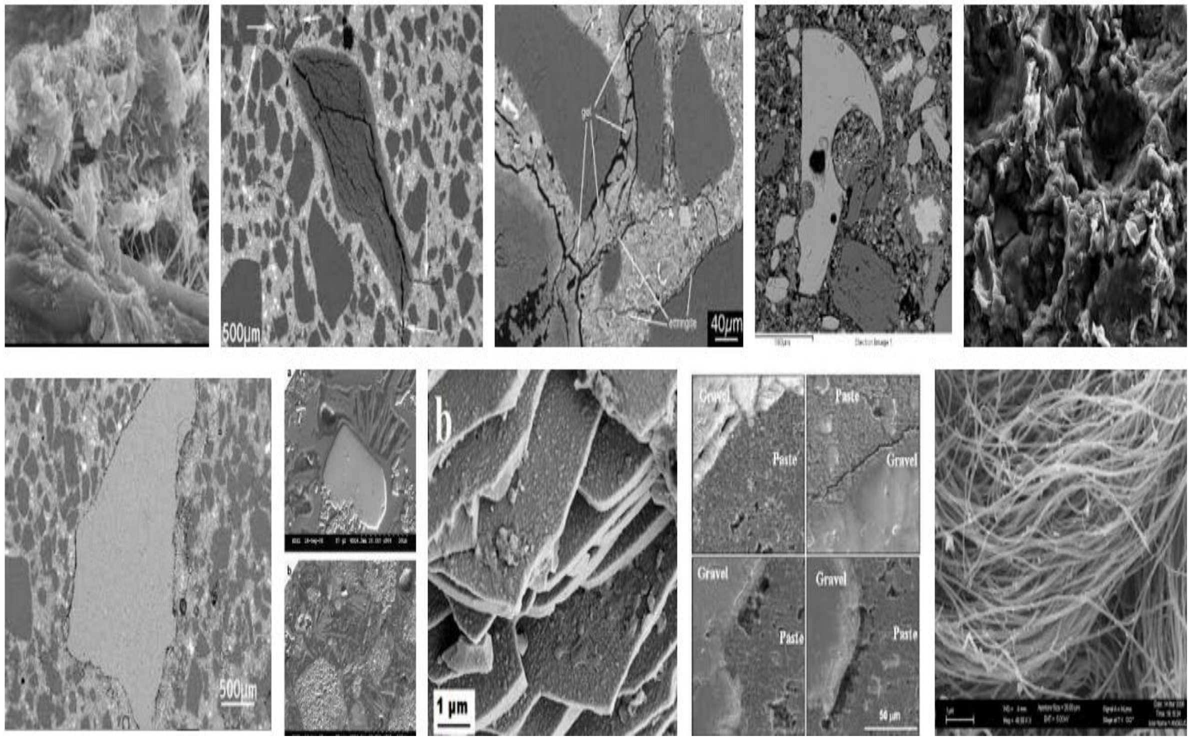

Figure 2. Electron microscope of concrete

As shown in Figure 3, finite element analysis method depends on the dividing up of a body into discrete elements, which may be triangles, squares or other defined shapes, and analyzing the response of the body as a whole as the sum of what the response is of each element of the body (Cook et al., 1974). Each element is characterized by the value of a quantity (stress, displacement) at the nodes (corners) of the element and values at points in between were estimated by interpolation. The method was developed in the 1950s for problems in structural engineering, especially in the aeronautical industry. The first usage of the term "finite element" came in 1960 and the generalization of the method to solve problems in fields other than structural engineering, such as heat transfer, came in the late 1960s. Since the calculations were numerical and elements were often small in relation to the size of components or structures, the use of the finite element method was somewhat restricted until cheap powerful computing facilities (hardware and software) became available. Initially, problems tackled by this method were one-dimensional but the developments of the method, especially with increased computing power available, has been extended to two and three dimensions.

Computational fluid dynamics is also based on breaking up a component or structure into a set of control volumes shown in Figure 4. For each control, volume equations will be set up to describe the flow of fluid (liquid or gas).The spread of fire or the cooling of a turbine blade by compressor air can be modeled. The technique has been in use since the 1960s, initially in the large aerospace companies (Jones et al., 1992). With the reduced cost of computer hardware and software, the use of computational fluid dynamics has increased greatly in the last ten years.

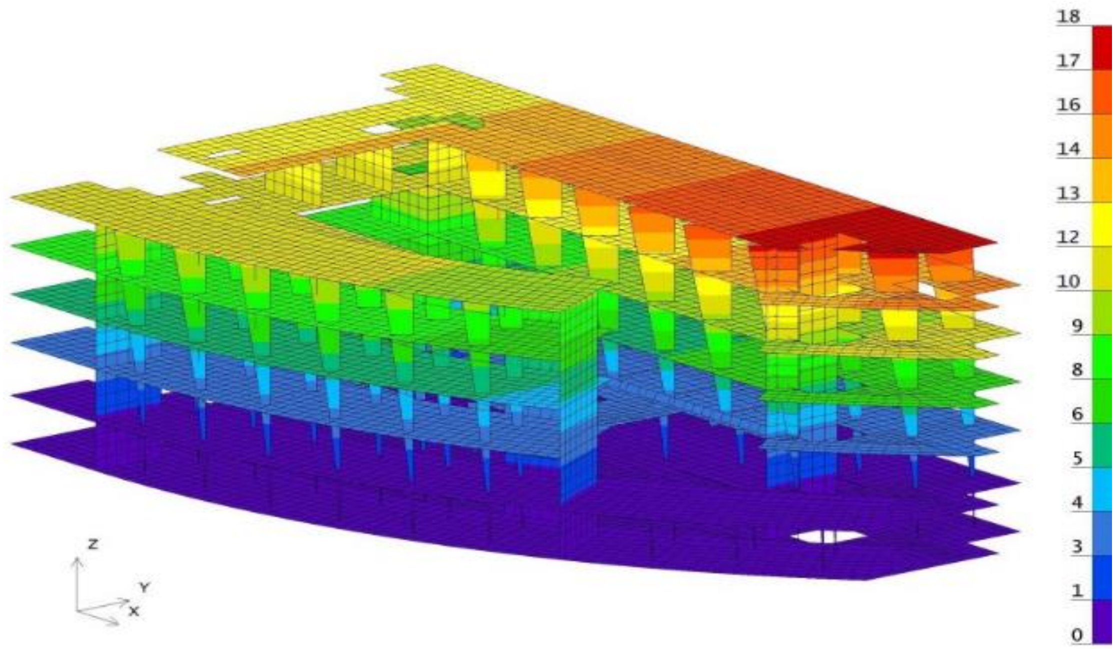

Figure 3. Finite element method

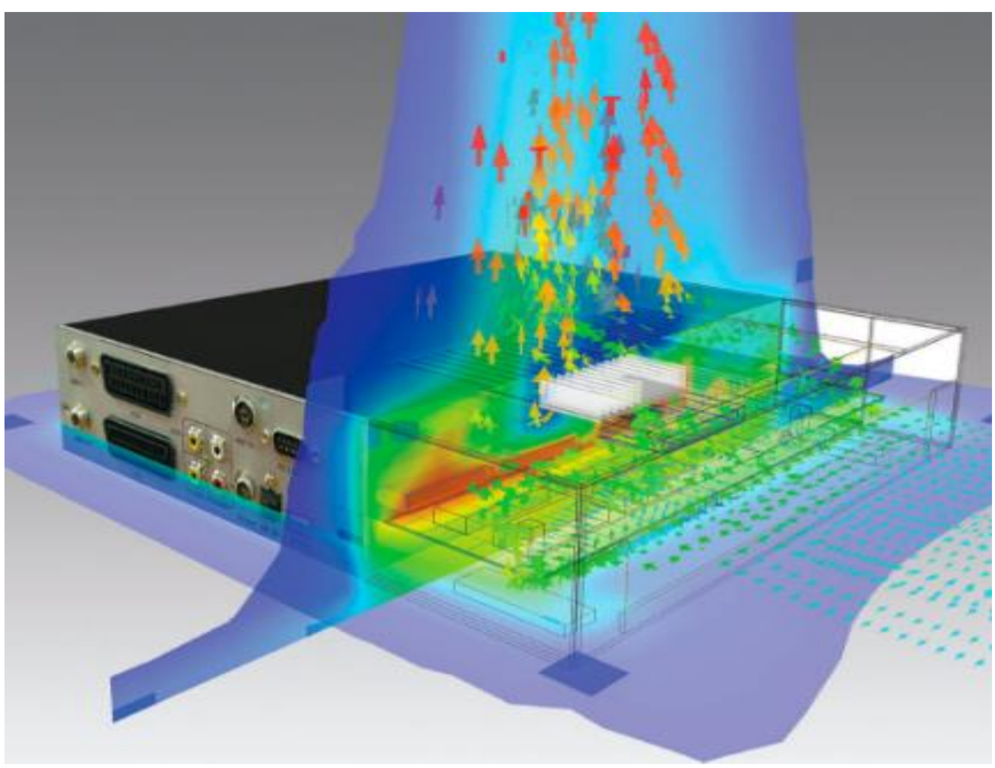

Figure 4. Computational fluid dynamics method

This has reduced the need for some wind tunnel testing and accelerated the production of solutions to design problems involving fluid flow. In forensic investigations of fire disasters, the use of computational fluid dynamics to determine the behaviour of fast moving flames has been invaluable and this has owed a lot to developments in the study of aerodynamics.

In impact dynamics shown in Figure 5, the modeling of impact events has been considered vital precisely because experimental work in these areas can tend to be difficult, expensive or, in some cases, illegal. Examples could include the penetration of an aircraft skin by a fragment from a missile, the projection of a non-penetrating projectile against a fuel tank or the passage of a shock wave from a detonating explosive. Computational methods have become very important in this area. Methods have left the defence and nuclear laboratories over the last 15 years, especially as improvements in computational approaches to finite element analysis and computational fluid dynamics have made the implementation of models to dynamic processes possible (Senge et al., 1980).

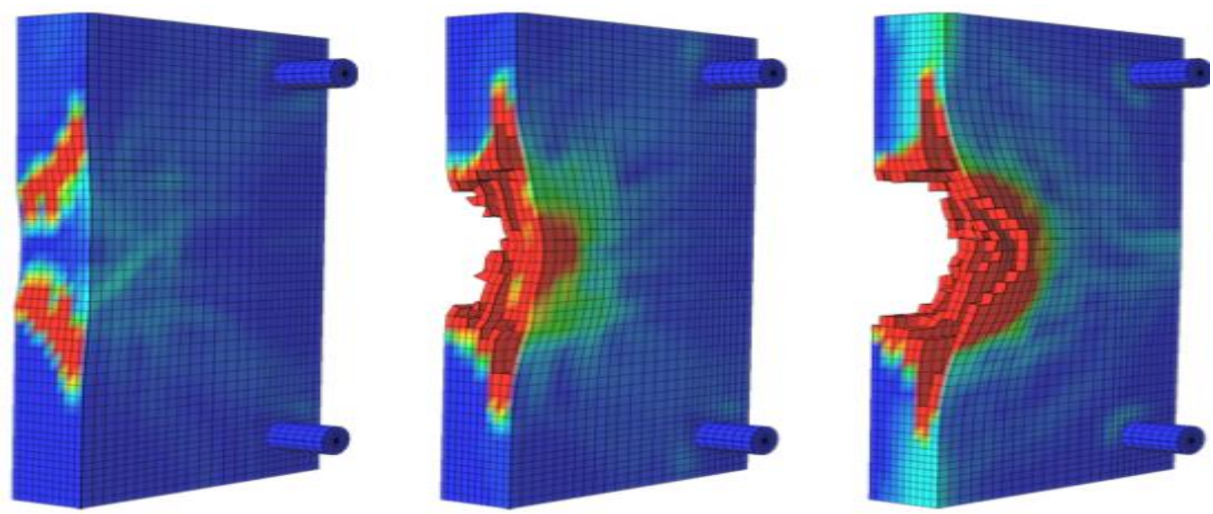

Figure 5. Impact dynamics method

3. BUILDINGS DECAY

The most common failures in building fabric can usually be traced back to one of three basic causes (Mosquera et al., 2002). These are poor construction, inappropriate repair or neglect. Although it is tempting to imagine that all old buildings were soundly and robustly built this is not necessarily true. Medieval structures may not have foundations in the sense that would think of them whilst Georgian or Victorian buildings might have an outer face of stone tied back to the structure with iron cramps, which are susceptible to rust.

There can also be a considerable difference in the quality and durability of the stone itself - granite is generally thought to be a very hard wearing stone whilst some limestone, for example, clunch or chalk, is very soft and may be more prone to decay (Ganiron Jr, 2014). Flint, on the other hand, is a very durable material but its rounded shape can make it difficult to form a strong bond alongside rectangular blocks of masonry.

Figure 6. Poor construction

The issue of inappropriate repairs frequently crops up when dealing with historic buildings. One of the most common is the use of modern cement mortar to repaint old walls. Whilst walls do need to be repainted from time to time to protect them from the weather, using a cement mortar is likely to increase the rate of decay and cause a great deal of damage (Ucol-Ganiron Jr, 2012). Such work is usually carried out with the best of intentions but is ultimately harmful to the building fabric. In such a case, it would have been better to seek professional advice about the specification for the repointing works and appoint a contractor familiar with traditional lime mortars. Other examples are the use of chemically injected damp proof courses or the application of proprietary water repellent solutions or modern emulsion paints to old walls (Van Hees, 2001). Such products will often prevent the proper evaporation of moisture from the wall and can exacerbate any inherent problems of dampness.

Figure 7. Inappropriate repair

However, in most cases, neglect is the main cause of premature building decay. The signs of neglect include broken rainwater goods, blocked air grilles and plants growing in gutters. All of these problems will encourage moisture to penetrate the fabric and prevent its evaporation. If the fabric becomes excessively damp this might lead to blistering paint and plaster, increased rates of decay in masonry and the possibility of timber decay and insect attack. High levels of moisture and excessive fluctuations in temperature can also encourage the movement of soluble salts in masonry structures (Ganiron Jr, 2015). Salt movement is characterized by blooms of white crystals on the surface of walls (efflorescence) and can cause considerable damage to plaster and paintwork (Cardell et al., 2003). In extreme cases, problems caused by excess moisture might even lead to walls becoming unstable, a potentially serious structural issue

4. HISTORY OF OLD GSIS BUILDING

On the first year of the Commonwealth period, a significant piece of legislation that would, later on, become the touchstone of other retirement laws was passed into law. Commonwealth Act 186, creating the Government Service Insurance System (GSIS) was approved on November 14, 1936, at a Special Session of the First National Assembly. The GSIS was established to promote the efficiency and the welfare of the government employees and to replace the different pension plan existing then. It was a consolidation of all laws on social security. With a starting capital of two hundred thousand pesos and 88 employees, the GSIS began its operation on May 31, 1937, in a building on Tanduay Street in San Miguel, Manila.

The main function of the GSIS was to provide compulsory life insurance coverage to all regular and permanent employees of the Commonwealth government, the National Assembly, the Metropolitan Water District, members of the judiciary, and officers and enlisted men of the Regular Force of the Philippine Army (Ivan, 2012). The GSIS is a government agency that provides financial assistance to its members through its different loan windows to help them obtain funds for specific purposes like building a house, augmenting funds for their family daily needs or even for investment purposes. On the part of GSIS, such extension of service also serves as an investment opportunity as funds entrusted to the system are earning interest income.

The ten year preparatory period for the Philippine independence was interrupted when the Japanese started the war in the Pacific. The GSIS was barely four and a half years old when the World War II hit the Philippines. On May 1954, GSIS building in Arroceros corner Concepcion Streets in Ermita, now known as Villegas corner Lopez Streets, Manila was constructed (Olivar, 2014). This five-storey structure covers 10,818.10 square meters.

According to the Urban Roamer (2014), the Government Service Insurance System (GSIS) was completed in 1957, one of the new structures to rise after the devastation of World War II to reflect a sense of optimism and zeal of a country rising from the ashes of war, not to mention having just been granted its sovereignty once more. Its architect is Federico Ilustre, the supervising architect of the Bureau of Public Works who also designed other notable structures built during that time, particularly the Quezon Memorial Shrine.

Figure 8. Old GSIS building in Arroceros Street, Manila

The building has been described as a structure incorporating elements of neoclassical and modern styles of architecture, giving it a unique look that blends old and new together in a unique design. For almost 40 years, this unique structure served as the home of the GSIS until it eventually moved by the early 1990s to a more sprawling complex at the reclamation area in Pasay. At one point or another, the building also served as offices for the Ministry of Education, Culture, and Sports, as well as that of the Office of the Ombudsman.

Since then, the old GSIS Building has been under a state of dereliction and decay as it has remained unused for years now, save for its grounds which is being used as a parking lot. Over the years, there have been rumors that the building was sold to a developer, notably to the one behind the mall right across it to serve as the mall's annex building.

As it turns out, it was not the case so some can somehow breathe a sigh of relief. But that does not mean that the building is safe from the wrecking ball. At this point, the details are murky as to whether at least the design of its facade will be retained for the new Manila Hall of Justice or will a new building rise altogether. Considering its significance in the post-war architectural history of the country, we should at least keep abreast of the developments to come and hope at least that its legacy would be preserved for future generations (Philippine History and Architecture, 2016).

The GSIS vacated this building in late 1980's and moved to a modern building in the Manila Bay Reclamation Area in Pasay City.There was nothing wrong with the GSIS building when the employees left the building structure back in the late 1980's. The main reason why the GSIS building was vacated because the system is moved to a new building situated in the Manila Bay Reclamation Area in Pasay City.

On January 14, 2006, at around 5 pm, a fire was spotted at the rear right portion of the 5th floor of the GSIS building. The fire was raised from 2nd alarm to 5th alarm in a span of 3 hours [6]. At the 4th hour, the fire was under control. The incident caused the five-storey building to lose its strength due to heat in addition to the exposure of reinforcement due to weathering and deterioration of the structure as years pass by.

As for the serviceability of the building as its main concern, serviceability is its priority characteristic. For civil engineers, serviceability refers to the conditions under which a building is still considered useful. Should these limit states be exceeded, a structure that may still be structurally sound would nevertheless be considered unfit. It refers to condition others than the building strength that renders the buildings unusable. Serviceability limit state design of structures includes factors such as durability, overall stability, fire resistance, deflection, cracking and excessive vibration.

The external part of the GSIS building shows damage, one of the causes is deterioration due to time, broken window glasses collapsed small strip of concrete on the 5th floor, yet aside from the seemly deteriorated facade the structure still stands firm. With the help of this study, the possible causes of its abandonment and the remedial measures may be discovered for a potential reuse of this structure.

The inquiry to be conducted is the forensic investigation of abandoned GSIS building in Manila, some weaknesses in the design, human error due to oversight or carelessness and the comparison of design codes used in the design of the structure and the present design codes will be revealed. This will benefit the city of Manila, the owner of the property, the civil designers for them to incorporate good designs that may cope with serviceability requirements for a long period of time and the students taking up civil engineering program because they can make the findings of this study as a basis for good design.

The study was based on the intended utilization of the structure as determined from architectural and structural plans but not lower than the building code regulations. Occupancy, a load of the structure is determined for load determination such as vertical and lateral load analysis and must check the allowable capacities (bending, shear, and deflection) as prescribed by the code.

This study will determine the capability of the structure to cope with the serviceability requirements in its present condition, the structural members, fire resistance, the mechanical systems and electrical wiring systems and installation, sanitation facilities, and location.

5. RESEARCH METHODOLOGY

Descriptive method of research was used by the researcher to gather information about the present existing condition of the abandoned GSIS building in Manila. The principal aim of the researcher in employing this method is to describe the nature of the situation of the building as it exists at the time of the study and to compare the different editions of design codes of ACI. The researcher utilized the descriptive method of research in three major areas a) condition of the abandoned GSIS building in terms of structural members; b) present serviceability status of the building that can does it cope with the present serviceability requirements of buildings; and c) comparison of ACI design codes and utilizing it in STAAD to generate the difference in the design from the edition of ACI codes used.

Surveys from the engineers who inspected the GSIS building in Manila is used and also ocular inspection and personal site investigation and visits were done to personally verify the condition of the structural members of the abandoned GSIS building in Manila. Structural plans of the abandoned GSIS building are used to know the actual dimension of structural members. With the use of STAAD software program, the loadings and capacities of the building were generated. The design codes of ACI and NSCP were used to compare the capacities and loading from which the design of the structure was based.

The researcher formulated different ways of how a project develops. The researcher views the visual appearance of concrete after a fire can be quite shocking with extensive blackening often accompanied by spalling and cracking. Of more importance, though, is the depth and extent of the fire damage. The assessment of abandoned GSIS building can be divided into four stages. These are preliminary inspection, on site assessment of damage (by visual inspection, breakouts, and/or non-destructive testing), laboratory testing of concrete and reinforcement samples to determine their residual strengths and confirm the depth of fire-damage and repair options.

Repair is usually possible but a key to assessing the type and extent of the required repairs is an accurate assessment of the damage caused by the fire. An important part of this assessment is evaluating temperature profiles and residual strength of the concrete. There are some techniques that can be used in repairs. These are visual inspection and hammer soundings, nondestructive testing (including rebound hammer, ultrasonic pulse velocity - UPV), sampling (coring drilling) and subsequent laboratory testing (including petrographic examination, and strength testing of concrete and reinforcement samples.

Of these techniques, the petrographic examination is used for estimating the depth to which the concrete has been damaged (Ingham, 2009). Concrete exposed to fire undergoes a progressive series of mineralogical changes that can be investigated by petrographic examination. The appearance of a pink/red discoloration which coincides approximately with the onset of significant loss of strength due to heating is one of the several changes which can be seen. The maximum temperature attained and the temperature profile can be assessed.

6. ANALYSIS AND INTERPRETATION OF DATA

6. 1. Deterioration in relation with service life of concrete

As shown in Table 1, the probability of deterioration damage in relation with the service life of concrete obtained 0.99, 2.09, 3.3, 4.4, and 5.50 vector damage state for every 10 years in the span of 50 years. For the year 2012, the probability of deterioration damage is at 5.83. This implied that the probability of state of the abandoned GSIS building is also in poor condition

This implied that the probability of the state of the abandoned GSIS building is also in poor condition. In 1964 and 1974, the state of the structure is in good condition. State of the structure is still acceptable in 1984, in fair condition in 1994 and finally in poor condition in 2004 and 2012. Table 2 shows the damage levels on reinforced concrete due to steel corrosion.

There are 7 states of structure which are state 1, state 2, state 3, state 4, state 5, state 6, and state 7. The state indicates the damage levels of the reinforced concrete based on the probability mass function of the concrete structure wherein there is no damage in state 1 and states 6 and 7 indicate extensive damages on the concrete structure. The visual indications are cracking, spalling, color changes, loss in steel section and deflection.

Table 1. Probability of deterioration damage

Span (years)	Year	Damage State
10	1964	0.99
20	1974	2.09
30	1984	3.30
40	1994	4.40
50	2004	5.50
58	2012	5.83

Table 2. Damage levels on reinforced concrete

Visual Indications	1	2	3	4	5	6	7
Color Changes	None	Rust stains	Rust stains	Rust stains	Rust stains	Rust stains	Rust stains
Cracking	None	Some longitudinal	Severe longitudinal	Extensive	Extensive	Extensive	Extensive
Spalling	None	Rust stains	Some longitudinal	Extensive	In some areas steel is no more in contact with concrete	In some areas steel is no more in contact with concrete	In major areas steel is no more in contact with concrete
Loss in Steel Section	None	Some longitudinal	5%	10%	25%	Some stirrups broken. Main bar buckled	Most stirrups broken. Main bar buckled
Deflections	None	Rust stains	Rust stains	Rust stains	Rust stains	Apparent	Apparent

6. 2. Condition of the structural members

Cylinder debris was taken from the abandoned GSIS building having a diameter of 76 mm, a height of 70 mm, an area of 4536.46 mm² and weight of 1kg was tested shown in Table 3. A compressive stress of 4.36 MPa is obtained from the test under a compressive load of 19800 N.

Table 3. Sample of concrete debris of abandoned GSIS building

Debris Sample	Diameter (mm)	Area (mm^2)	Height (mm)	Weight (kg)	Load (N)	Stress (N/mm^2)
Cylinder Debris	76	4536.46	70	1	19800	4.36

As shown in Table 4, serviceability requirements for structural members include deflection, cracks in tolerable limits and minimized vibrations. The structural members do not exceed the maximum deflection. Cracks were kept in tolerable limits and only minor vibrations were felt inside the structure. The abandoned GSIS building is still in serviceable condition in terms of its structural members.

Table 4. Serviceability requirements of structural members

Serviceability Requirements	Status	Effects on Structure
Deflection is adequately small.	Does not exceed maximum deflection.	Still in serviceable condition.
Cracks in tolerable limits	Still in tolerance limits	Still in serviceable condition.
Vibration minimized	Minor vibrations were felt	Still in serviceable condition.

Deterioration of concrete greatly affects the strength of concrete of abandoned GSIS building. For instance, age weakened the concrete strength of the concrete through time. Corrosion occurred on exposed reinforcing bars or metal reinforcements doubled the volume of reinforcing bars and then applied pressure to the surrounding material that results in stress levels greater than the tensile strength of concrete.

As a result in table 5, there are concrete fractures and separation of rebars occurred. Cracks exist in concrete at its early ages later expand and widen due to service conditions. Heat conduction and temperature changes decreased the strength of both the concrete and its steel reinforcements

Table 5. Causes of deterioration and its effect on concrete structural members

Causes of concrete deterioration	Effects on Concrete Structural Members
Age	Weakened the concrete strength through time. There is the reduction of load carrying capacity
Corrosion of rebars	Doubled the volume of reinforcing bar and applied pressure to be surrounding material that resulted in stress levels greater than the tensile strength of concrete.
Cracks	Cracks which exist on concrete at early age expand and later widen during service conditions..
Heat Conduction	Heat and temperature changes affected the concrete and its steel reinforcements resulting in the decrease of concrete strength.
Moisture Transfer	Moisture on steel reinforcements resulted in corrosion and weakening of steel strength.

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Figures 9. Spalling of concrete to beams and a column caused by fire

Moisture causes corrosion of steel reinforcements and resulted from the in the decrease of tensile strength of steel reinforcement making it weak. These factors cause the deterioration of concrete thus making the concrete less serviceable.

In addition, photographs of the various defects observed on the fire-affected concrete surface are also presented. Figures 9, 10 and 11show various surface defects observed on some of the fire-affected members.

Figure 10. Reinforcement exposed on a beam soffit following a fire

Figure 11. Concrete spalled from a slab soffit revealing pink/red discoloration

6. CONCLUSIONS

Deterioration damage of concrete of the abandoned GSIS building is increasing as the years pass by. As the concrete becomes old, the concrete strength decreases that shortens the service life of concrete. The structural members do not exceed the maximum deflection. Cracks were kept in tolerable limits and only minor vibrations were felt inside the structure.

The abandoned GSIS building is still in serviceable condition in terms of its structural members. Corrosion occurred on exposed reinforcing bars or metal reinforcements doubled the volume of reinforcing bars and then applied pressure to the surrounding material that results in stress levels greater than the tensile strength of concrete. As a result, there are concrete fractures and separation of rebars occurred. Cracks exist in concrete at its early ages later expand and widen due to service conditions. Heat conduction and temperature changes decreased the strength of both the concrete and its steel reinforcements. Moisture transfer caused corrosion of steel reinforcements and resulted from the decrease of tensile strength of steel reinforcement making it weak.

There is a difference between the design loads used in the GSIS building in Manila from the present design codes of NSCP and ACI codes. This implies that standard design loads do not satisfy the requirements of the present design codes of NSCP and ACI codes.

To be able to use the abandoned GSIS building, the following recommendations are made: a) Change the use of the abandoned GSIS building in which the structure will have fewer occupants and fewer machineries installed inside the structure; b) Refurnishing the part of the building which is mainly damage by fire to lessen the effect of deterioration and to restore the area affected by fire; and c) Retrofitting of the structural members which need to be added support in carrying loads acting on it.

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