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Research on Technical Solutions to Renovate the Reinforced Concrete Constructions in Vietnam

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Abstract

During the use of constructions, they will be degraded. Due to the negative impact on structures such as increase in vertical load, horizontal windy load needs to evaluate the current state of the constructions before renovating, especially the current state of the main structural system whether necessary to carry out repair and reinforcement or not. In addition, the inspection of the current status constructions before renovating is also the legal basis for the granting of construction permits to renovate and repair degraded works. Reinforced concrete buildings in the coastal areas in Vietnam, in particular, are working in the marine environment leading to damage the reinforced concrete construction. It should be significantly noted. Although there have been legal documents related to the inspection of constructions issued in Vietnam, the detailed contents and procedures of institution for each type of construction have not been mentioned yet. Therefore, the topic research paper of "research on technical solutions to renovate constructions with reinforced concrete structures in Vietnam" is to improve the quality and efficiency of construction. This investigation in Vietnam is very essential. This study uses the method of surveying the current state of the construction works in use, using the experimental sampling method to analyze and evaluate the damage of the work, then propose typical solutions to repair construction. The purpose of this study is to provide a process to check the damage of the works, and to propose solutions to repair them. This work is very important and has practical significance, helping managers to maintain works better.

Keywords

Reinforced Concrete, Building Renovation, Reinforced Concrete House

1. Introduction

A building construction has a lifespan. It is necessary to be determined in the design stage to ensure the normal operation during the lifespan. The lifespan of the building construction is related to the durability and threshold of the durability. The guarantee of normal operation is understood as the assurance of the functions based on the limited state safe of bearing and use [1].

During the construction process, the buildings have been affected by various factors, the lifespan as well as their sustainability are considered from the point of using constructions. The factors affecting the life of the buildings can be mentioned such as: external loading, internal forces in the structure of the building, ambient temperature, moisture in the air, deformation and shrinkage of the materials, the influence of the load-bearing capacity of the sub base layers [2]. For these reasons, there are many damaged and degraded buildings.

Currently, Hanoi-Vietnam has nearly 200 villas about 100 years old that have been seriously degraded and need renovation and repair [3]. Especially for coastal constructions, this is a strongly intrusion due to chloride ion Cl^-. Although most civil constructions are designed with a lifespan of over 50 years, the reality shows that damage occurs quickly, many buildings are damaged after only 10 - 20 years of using. Rapid and severe damage leads to very expensive repair costs and shortened life of the structure [4]. The port of Vietnam, Deterioration of the 5000 T wharf at ThiNai port is seriously degraded [5]. From the actual damage of the works and the analysis of the causes of damage as above, the author realizes that it is necessary to repair and renovate the damaged buildings.

Regarding this situation, clearly identifying the cause of the incident, researching and proposing solutions to safely manage construction works is very important in the maintenance of construction works. Investigating and evaluating construction incidents is an extremely complicated job, requiring a high level of expertise and a sense of responsibility towards society. Therefore, the investigation of any incident needs to be organized in a scientific and objective manner with the participation of experienced experts and modern technical equipment to properly identify the incident of the project or technical errors. In other words, any small mistake that distorts the judgment of the incident will lead to unbiased or even erroneous conclusions, so it does not help the management of the project.

Therefore, this study aims to approach, assess the causes and extent of damage to the constructions, and come up with solutions to repair and renovate to increase the life of the building constructions.

2. Causes of Damage

There are many causes of damage to reinforced concrete structures such as [6]:

a) Carbonation process

Carbonation is caused by the dissolution of CO_2 in solution in the pores of the concrete and reacting with calcium from calcium hydroxide and calcium silicate

hydrate to form the mineral calcite ($CaCO_3$). Aragonite can be formed in hot (high temperature) conditions. The primary cause of damage and deterioration concrete floor is carbonation, that occurs on carbon dioxide enters the concrete through small cracks and voids, reacting with hydroxides such as calcium hydroxide and form calcium carbonate. The product of the reaction lowers the pH in the concrete from 13 to 8. The reduction in alkalinity causes the embedded steel bars to corrode. However, carbonation does not accelerate the corrosion of steel bars.

The carbonation of concrete is a slow process. If the quality of concrete is good, the estimated carbonation rate is 1 mm/year. However, the carbonation rate is increased in concrete with low cement content, low strength, short curing time, high cement to water mixing ratio and high permeability. The relative humidity of concrete is another factor that controls the rate of carbonation. It peaks when the relative humidity of the concrete is between 50% - 75%. Therefore, carbonation can be neglected at relative humidity less than 25%.

Finally, carbonation affects parts of the concrete building that are directly exposed to precipitation, are shaded from sunlight, and have small concrete coatings.

b) Corrosion of reinforcement

The main causes of corrosion of reinforced concrete are concrete that is too thin or hollow, the source of H_2O, CO_2, O_2 and CL ions, salted materials during construction and rapid attack from seawater environment, sea water contains a lot of salt, the amount of chloride salt is 88% - 89%, sulfate salt is 10.5%, PH: 8.2 - 8.3, the strongest corrosion is sea gas and tides (low humidity will increase the O_2).

Corrosion of reinforcement is a main cause of concrete deterioration. It occurs when the pH of concrete drops to 10 or less, and chloride, oxygen, and moisture ions find their way in. The result is a greater mass of corrosion product than steel, which stresses the surrounding concrete and causes it to crack, delamination or peel. Corrosion of reinforcement embedded in concrete can be greatly reduced by placing concrete that is less permeable and free of cracks and providing adequate concrete cover over the steel bars.

c) Chemical reaction

Sodium, potassium, calcium or magnesium sulfates dissolved in soil, rainwater or groundwater can penetrate concrete, react with the hydrated compounds and expand, causing damage to concrete floors. In addition, internal sulfate influences create a material that absorbs water and causes significant blistering and cracking.

Using a low water-cement ratio and cement with a small amount of tricalcium aluminum is the best way to prevent sulfates from affecting concrete floors. Acid attack will dissolve the binder from the concrete surface, alkali-aggregate reaction produces an expansion product, and soft water attack erodes the cement paste in the concrete. Protective treatment of concrete surfaces can help prevent

acid attack. In addition, properly cured concrete with low permeability can reduce the rate of acid attack.

d) Overload and force impact

Early removal of formwork or storage of heavy materials or equipment can overload some aspects of the structure. For example, an impact device can lead to large-scale micro-cracking. A common form of impact overload occurs at the slab edges of joints on concrete floor surfaces.

Heavy loads on concrete create cracks and micro cracks. In addition, overload can occur due to changes in building performance without proper structural upgrades and unusual events such as earthquakes. Early removal of formwork or storage of heavy materials or equipment can overload some aspects of the structure. For example, a device impacted on structure can lead to large-scale micro-cracking. A common form of impact overload occurs at the slab edges of joints on concrete floor surfaces.

e) Effect of temperature

High temperature affects the quality of concrete. In the process of pouring concrete into the mold, water is the main ingredient in concrete, high temperature will increase the rate of vaporization, so in the concrete pouring process, a larger amount of water will be required. Besides, high temperature also increases the risk of cracking and reduces the durability of concrete.

During the time the concrete is hard enough, if concrete is exposed to high temperatures, it loses most of its compressive strength, flexural strength, and elasticity. In contrast, concrete with a high aggregate-cement ratio will have less compressive strength loss, and the lower the water-cement ratio, the lower the elastic modulus loss. As a result, water trapped in the concrete can cause "rock formation".

f) Concrete shrinkage

The carbonization process greatly increases the shrinkage of the concrete, causes micro cracks and accelerates the corrosion of the steel bars. Another factor is the high water content in the concrete mix which will push the cement to the surface. As a result, the concrete surface will dry before setting, causing shrinkage, cracking, cracking and loss of compressive strength.

g) Material composition ratio

As we all know concrete structure is a type of construction structure designed and composed by a mixture of cement, crushed stone, sand, water and other additives. Concrete floor structure is a concrete structure positioned with iron and steel cores. When the structural components should be mixed with the wrong formula or improperly joined ingredients, it will lead to the concrete structure being affected and often cause phenomena such as: cracked, broken floor surface, subsidence, collapse…

h) Geology

High buildings need deep foundations, and if a high-quality concrete floor to maintain quality for a long time is needed, a highly stable foundation is required.

Some types are appreciated in forming a sustainable base layer such as laterite, basalt soil.

For constructions built on a foundation in fields, ponds, swamps, and alluvial soil, the concrete floor is weak, which can easily cause cracks, subsidence or even collapse.

In addition, there are many other specific and objective factors that can affect and damage concrete floors.

3. Proposing Methods of Assessment and Technical Solutions to Repair and Renovate

3.1. Methods and Procedures for Assessing the Quality of Works

a) Read the project file

This stage is to gather all the information related to the work to be checked: design documents, construction documents and work completion.

b) Site survey

This stage aims to survey and evaluate the current status of the quality of the work and at the same time, it is possible to determine the necessary work contents to be performed, such as determining damaged structures, the extent of damage, deterioration. Figure 1 is depicted of construction survey process.

c) Testing and surveying the quality of building structures

In this phase, samples of damaged and degraded structures are collected and experiments are carried out to have a basis for evaluation.

d) Recalculate the load-bearing structure according to the actual results of the work.

In this work, to recalculate the load-bearing capacity of the building, to check the bearing capacity of the members. From there, there is data for analysis and assessment of the level of need for repair. As follows:

Analyze, evaluate and give technical solutions to apply. Based on the construction design documents, relevant normative standards to assess the current status of the quality of the works from the results of the inspection.

- Collect survey results, presented in the form of tables, figures, diagrams with comments, descriptions, notes, pictures...
- Processing and calculating survey results. Calculation results are usually presented in tables and graphs.
- Determine the cause of the damage, defects and incidents. Present comments on the current state of the test structure.
- Compare the survey results with the current design regulations, regulations and standards related to the construction inspection content.

3.2. Technical Solutions to Repair and Renovate Works

In this section, the study shows typical technical solutions that researchers can use to design for renovation and repair. Each different building has different shapes, sizes of components, and different damage, so when applying a typical

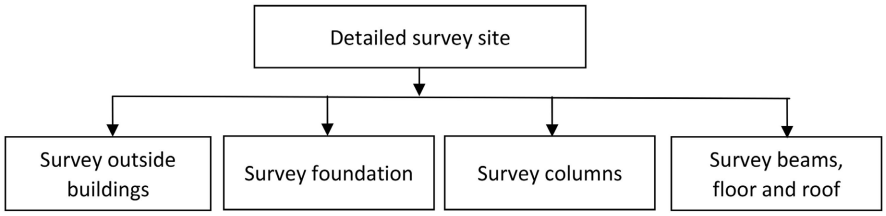

Figure 1. Survey flowchart.

design, it is necessary to calculate the bearing capacity of the structure to be repaired, from which determine the size, quantity of steel, concrete strength, repair materials accordingly. And in some cases, it is necessary to have a field test of the type of repair member, to determine their internal load capacity, to ensure that the repair work is sustainable.

a) Solutions to reinforce the foundation

Brick and stone foundation.

Figure 2 is a solution to cover the top of the foundation with concrete, which increases the distributed load capacity for the wing without increasing the size of the bottom of the foundation. While **Figure 3** is the solution to reinforce the foundation while expanding the bottom of the foundation. **Figure 4** shows the reinforcement method for a single foundation.

To solve this problem, it can use many different methods such as: breaking the protective concrete layer and welding steel bars, anchor bolts or other components to the old foundation, applying fresh cement mortar on the rough surface of the old foundation or change the aggregate composition in the concrete... to strengthen the connection at the adjoining positions.

Solution to strengthen the foundation by expanding the bottom of the foundation

Reinforce the foundation by expanding the bottom of the foundation, while increasing the burial depth by adding supporting structures below the old foundation. First of all, put more reinforced concrete slab below the old foundation, this solution does not significantly change the depth of foundation but still increases the bearing capacity of the foundation. Soil under the old foundation is dug 1 - 2 m deep and precast or cast-in-place reinforced concrete slabs are additionally arranged in these excavations. **Figure 5** is a solution to strengthen the single foundation by expanding the bottom of the foundation.

Reinforcement solution by switching foundation type

In the reinforcement of single foundation type, we can convert the single footing into ice foundation or ice foundation into raft foundation. This case occurs when the soil layer under the foundation has a large deformation, there is a significant settlement difference between the single foundations. Reinforced concrete wall was added to connect the old single foundation together to convert the single footing under the column into ice foundation. **Figure 6** is Reinforcement solution by switching foundation type.

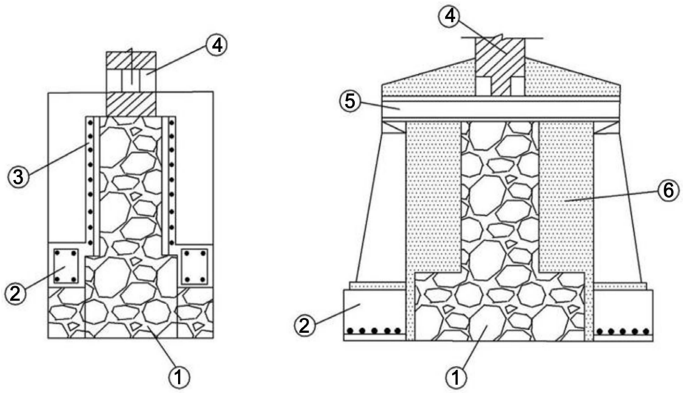

Figure 2. Proposal for reinforcement of brick (stone) foundation. In **Figure 2**: 1—foundation; 2—concrete beams; 3—reinforced reinforced concrete; 4—building wall; 5—horizontal steel beams; 6—full concrete block.

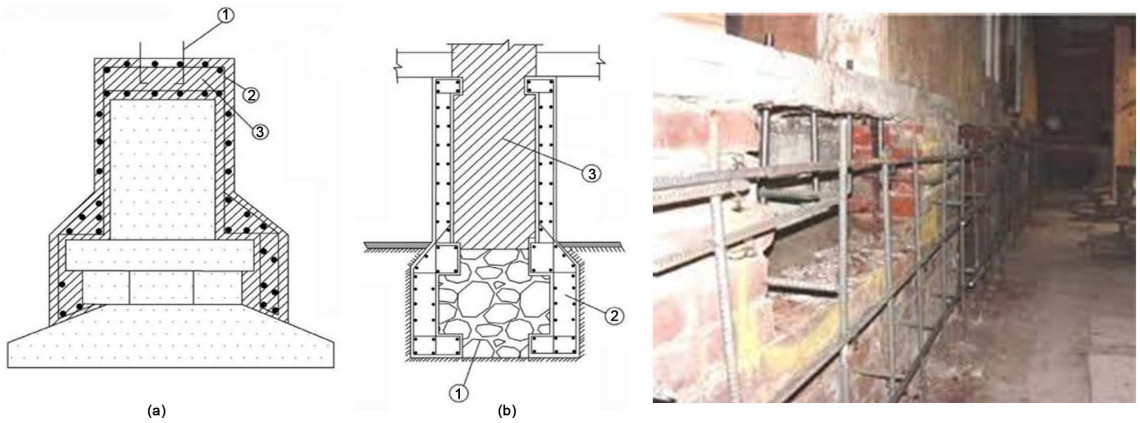

Figure 3. Proposal for reinforcement of brick (stone) foundation-continued. In **Figure 3**: (a) is Solutions to reinforce the foundation without expanding the bottom of the foundation 1—bolts; 2—welded wire mesh; 3—coat texture; (b) is Solutions to reinforce the foundation with widening of the bottom of the foundation: 1—foundation; 2—reinforced wrapping structure; 3—foundation wall.

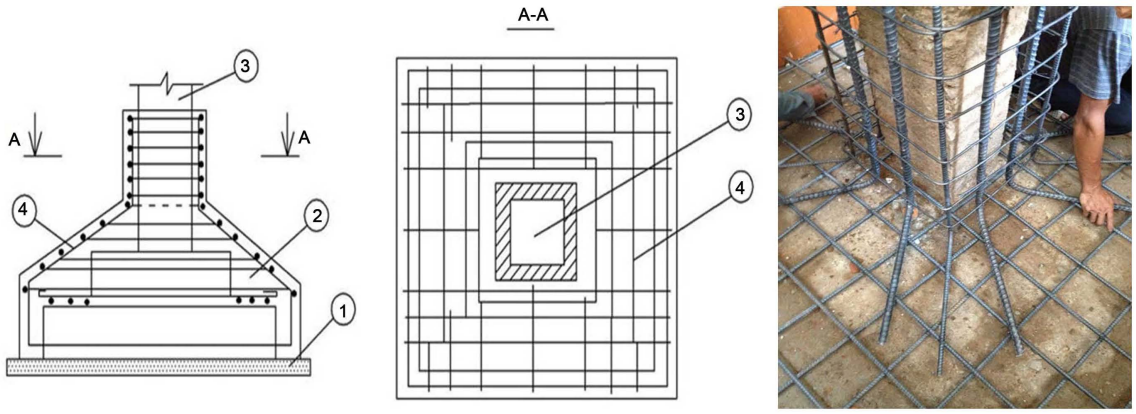

Figure 4. Proposal for reinforcing a single foundation by extending the foundation. In **Figure 4**: 1—foundation; 2—coat texture; 3—columns; 4—reinforcing steel.

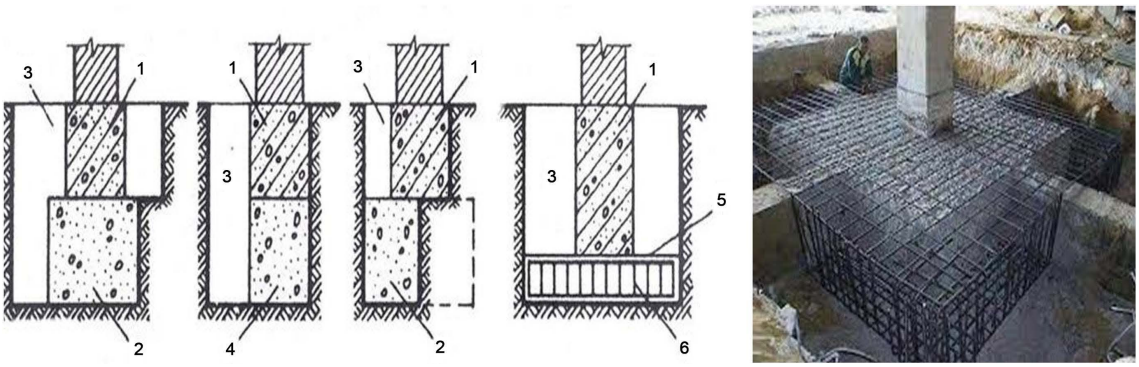

Figure 5. Proposing a solution to strengthen the single foundation by expanding the bottom of the foundation. In **Figure 5**: 1—foundations; 2—column; 3—dug pit; 4—wall; 5—concrete slabs; 6—steel.

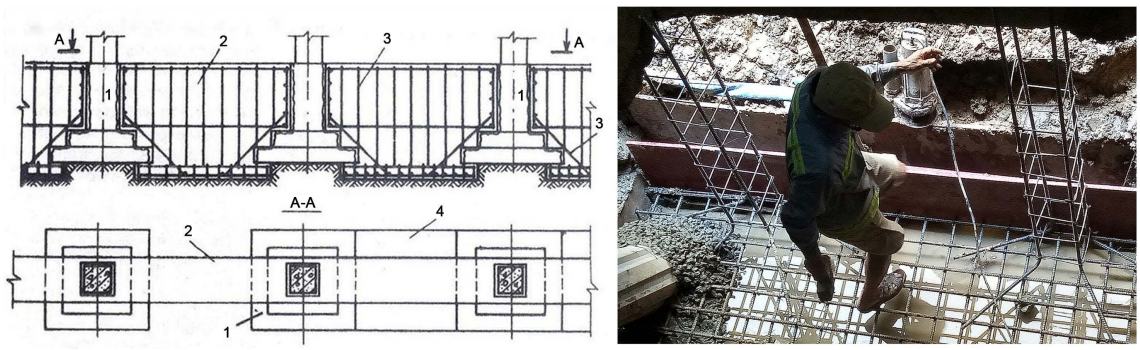

Figure 6. Reinforcement solution by switching foundation type. In **Figure 6**: 1—single foundation; 2—concrete wall; 3—bearing steel; 4—the area of the foundation is enlarged.

Solutions to reinforce the foundation with reinforced concrete piles

This solution is often used in cases of shallow foundation reinforcement, when the load of the structure must be transmitted to the good soil layer located very deep at the bottom of the foundation, or especially the foundations located in places with high groundwater levels. The ice foundation can be reinforced by arranging 1 or 2 more rows of reinforced concrete piles on one side or both sides of the foundation, while for a single foundation, piles are often arranged around to form the foundation. Sturdy base for the foundation. **Figure 7** is Solutions to reinforce the foundation with reinforced concrete piles.

b) Some solutions to reinforce and repair concrete and steel columns.

Reinforcement and repair of reinforced concrete columns can be done with options such as expanding the column cross-section, using steel for external cladding, reinforcing with composite fiber panels. The choice of plan should pay attention to whether it affects the architectural space of the work or not and the suitability of construction. The size of the expanded concrete and the additional reinforcement should be calculated on the basis of the lack of bearing capacity of the existing column structure. **Figure 8** is Actual photo reinforcement by increasing column cross section size in project.

c) Proposing some solutions for reinforcing steel concrete beams

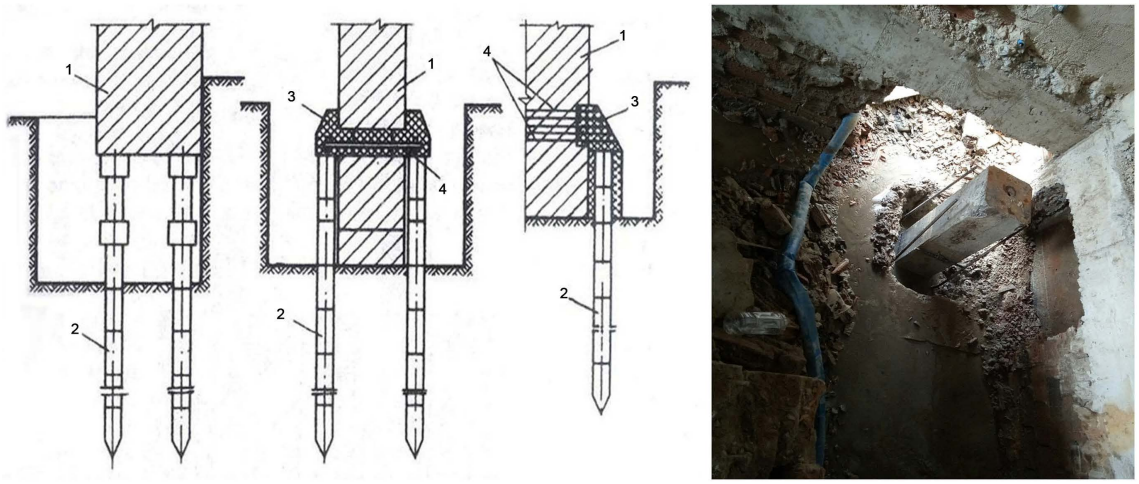

Figure 7. Solutions to reinforce the foundation with reinforced concrete piles. In Figure 7: 1—foundation; 2—steel concrete pile; 3—steel concrete beams; 4—steel concrete braces.

Figure 8. Actual photo reinforcement by increasing column cross section size in project, Hanoi, Vietnam.

The reinforcement and expansion of the steel-concrete beam cross-section is mainly aimed at increasing the beam height, thereby increasing the bearing capacity and increasing the stiffness of the beam. Bearing steel area and extension thickness should be determined through calculation. Figure 9 is some forms of reinforcement of beam structures.

Reinforcement of reinforced concrete beam bending resistance by gluing steel plate:

The feature of this method is simple reinforcement, little influence on the shape and size of the reinforcement structure. Increase the bearing capacity and stiffness of the reinforced structure. The adhesion between the steel plate and the concrete structure determines the reinforcement efficiency. Using the method of gluing steel plates to strengthen bending and shearing forces. Figure 10 is actual photo Reinforcement of reinforced concrete beam bending resistance by gluing steel plate.

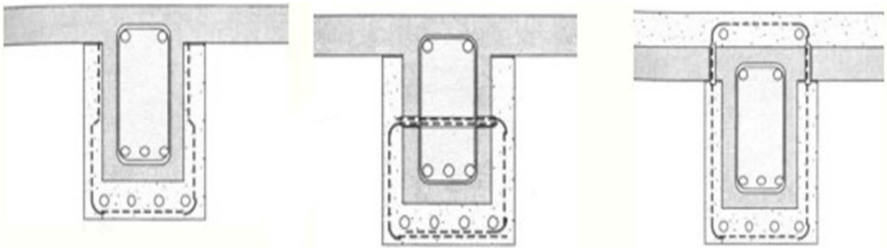

Figure 9. Some forms of reinforcement of beam structures.

Figure 10. Actual photo Reinforcement of reinforced concrete beam bending resistance by gluing steel plate.

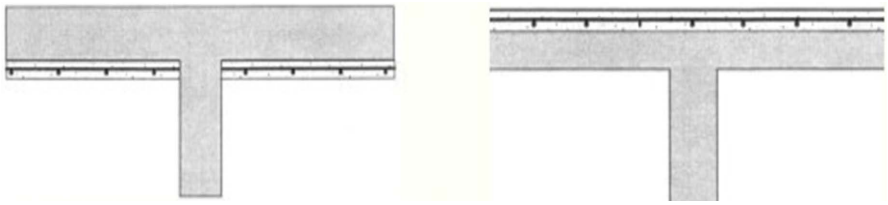

Figure 11. Some solutions to increase the thickness of concrete floors.

d) Some solutions to increase the thickness of concrete floors

Reinforcement to increase the thickness of reinforced concrete floors can be applied to slabs subjected to negative moments and slabs subjected to positive moments. In this case, the method of increasing the reinforcement cross-section is mainly applied. When carrying out the reinforcement of the positive moment area, it should be noted the difficulty of reinforcement because it is performed at the bottom of the slab. It is recommended to use non-shrink, self-flowing cementations mortar. Figure 11 is some solutions to increase the thickness of concrete floors.

4. Conclusions

Research on some technical solutions to renovate buildings with damaged and degraded reinforced concrete structures is extremely necessary, in order to increase the service life of the works and minimize the risks of losses due to damaged works.

The research has achieved the set objectives: Proposing the process of checking the current status of reinforced concrete structures and proposing some solutions to repair and renovate to improve the quality of the works.

The study proposes some typical structural reinforcement solutions, but applying to each project should be based on calculation results and detailed design.

The research results have practical applicability, making them a valuable reference for those doing the work of project evaluation and renovation.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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