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Problem and Damage of Steel Structure in Thailand

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บทคัดย่อ

งานวิจัยนี้มุ่งเพื่อแสดงให้เห็นถึงปัญหาและความเสียหายที่เกิดขึ้นในโครงสร้างเหล็กต่างๆที่ตั้งอยู่ในสถานที่ที่แตกต่างกัน รวมถึงแยกแยะและระบุปัจจัยต่างๆที่ก่อให้เกิดความเสียหายกับโครงสร้างเหล็ก ทั้งปัจจัยที่ส่งผลในทางอ้อมและปัจจัยที่เป็นต้นเหตุของปัญหา โดยใช้วิธีการตรวจสอบพินิจเพื่อตรวจสอบโครงสร้างจริง ตามมาตรฐานการตรวจสอบของไทยและสากล และสัมภาษณ์บุคลากรที่เกี่ยวข้องกับการบำรุงรักษาโครงสร้างนั้นๆโดยตรง เพื่อให้ทราบถึงมาตรการการรับมือความเสียหาย และปัญหาต่าง ๆ ที่เกิดขึ้นกับโครงสร้าง ทั้งขณะสร้าง และหลังสร้าง ซึ่งผลการวิจัยและรวบรวมข้อมูลได้แสดงให้เห็นว่าโครงสร้างเหล็กส่วนใหญ่นั้นประสบกับปัญหาการเกิดสนิม และความเสื่อมสภาพของสีกันสนิม โดยความรุนแรงของความเสียหายนั้นขึ้นอยู่กับ สภาพแวดล้อมของโครงสร้างและความสม่ำเสมอของการบำรุงรักษาโครงสร้างซึ่งเป็นผลกระทบโดยตรง แต่มีความเสียหายบางประเภทที่เกิดจากปัจจัยทางอ้อม เช่น ความบกพร่องของรอยเชื่อมที่มีสาเหตุมาจากขั้นตอนการก่อสร้างที่ไม่ดี ช่างเชื่อมขาดความชำนาญ และขาดขั้นตอนการตรวจสอบที่ถูกต้อง โดยในงานวิจัยฉบับนี้ได้ให้ข้อเสนอแนะในการแก้ไขปัญหาไปใน 2 ทิศทาง คือ การแก้ปัญหาระบบการบำรุงรักษาที่ไม่ดี และการแก้ปัญหาขั้นตอนการก่อสร้างที่ไม่ดี สำหรับทิศทางแก้ปัญหาทิศทางแรกเสนอให้มีการร่างมาตรฐานหรือแนวทางในการตรวจสอบและการบำรุงรักษาโครงสร้างเหล็ก และสำหรับทิศทางที่สองเสนอให้มีการร่างและเฉยแพร่ ข้อกำหนดของวัสดุเพื่อควบคุมคุณภาพของวัสดุเหล็กที่มาจากผู้ผลิตต่าง ๆ ทั้งในประเทศและนอกประเทศ และร่างหนังสือคู่มือการก่อสร้างสำหรับโครงสร้างเหล็กให้มีความแข็งแรงทนทาน

ABSTRACT

This research focused on indicating the problem and damage that occurred on different steel structure in different location and identifying the cause of damage, both root cause and indirect cause. This has been done by using the methods of visual inspection on the real structure based on an existing Thailand and international standards and interviewing the maintenance personnel who directly involved the maintenance work to acknowledge the countermeasure and problem that occurred to the structure during construction and after construction. The result indicated that the majority of the steel structures have corrosion damage and the deterioration of steel coating, which the severity of the damage depend on the surrounding environment and the frequency of the maintenance work. Furthermore, there is the other type of damage such as welding defects that caused by poor construction process poor workmanship of the welder and lack of correct inspection procedures. The suggestion of solution was divided into two approaches; 1) maintenance approach, 2) construction

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approach. For the first approach, standard or guideline for the inspection and maintenance of the steel structure should be drafted. For the second approach, the followings should be drafted or established; 1) material specification to control the quality of the steel product from the different manufacturers (domestic and foreign factories) and 2) construction handbook for the durable steel structure.

1. Introduction

Maintaining the durability of a structure during its service life is important for every type of structure. Therefore, an inspection, evaluation and repair are necessary to keep the structure in a good condition.

As a material for the main structure, steel is known to be used for truss structure, but steel also has been used widely in bridge structure, expressway structure, billboard structure, and power plant structure.

Nowadays, steel structures are facing with a deterioration problem. Without any maintenance action, the structure will be gradually damaged. Since, Thailand has been lacking of a standard or guideline to maintenance the deteriorated steel structure, make this problem remains unsolved.

This research mainly focused on three main topics; 1) indicating the problem and damage that occurred to the steel structure, 2) identifying the indirect and root cause of the problem and 3) giving suggestion for solution of those problems.

2. Literature Review

Presently, the standard of Thailand that was published by two main organizations which are “Department of Public Works and Town & Country Planning”, and “Thailand Industrial Standards Institute” were the main standards used in construction industry.

Unfortunately, Thailand standards did not cover the maintenance of steel structures, caused an overlook on maintenance tasks for steel structure.

Nevertheless, the current Thailand standard which specified the detail involving maintenance tasks was DPT 1561-51 to DPT 1565-51; [1], which stated about Non-destructive testing (NDT) for welding inspection work, divided in to five NDT methods as follows; 1) Visual inspection (VT), 2) Ultrasonic Testing (UT), 3) Magnetic particle testing (MT), 4) Liquid Penetrant Testing (PT), 5) Radiographic Testing (RT).

Also, TIS 2387- 2555; [2] which specified the inspection of anticorrosive paint for steel, using photographic reference method for determining degree of blistering and degree of rusting according to quantity of defect and size of defect.

Furthermore, an international standard were used widespread in Thailand, such as steel fabrication factories, and maintenance department of a steel power plants. The standards are including standards from a developed countries such as AWS D1.1/D1.1M; [3] American standards for welding inspection criteria, JASS 6; [4] Japanese standards for construction and inspection, and a standard from International Standard Organization (ISO); [5] for Paints and varnishes evaluation.

It is obvious that the mentioned standards were constructed to apply for construction, fabrication, and inspection for new structures but not for the maintenance work in order to maintain structure durability after constructed.

3. Methodology

Firstly, real site inspection was performed to indicate the problem and damage that occurred to the steel structure. Secondly, the maintenance personnel were interviewed in order to obtain relevant information to identify the indirect and root cause of the problem.

The target structures were expressways, billboards, power plants, and roof structures, which were constructed by using steel as their main structure.

3.1 Real site inspection

Visiting the real construction site or a real structure is the best way to acknowledge the problem and damage of the steel structure under different environments, locations, and functions.

The inspection criteria were followed the standard in literature review, both Thailand and International standards.

Site inspection was mostly carried out by using Visual inspection (VT), since this method does not affect capacities, appearances, or functions of the steel structures.

Visual inspection flow chart and criteria used in this research was specified in Fig. 1.

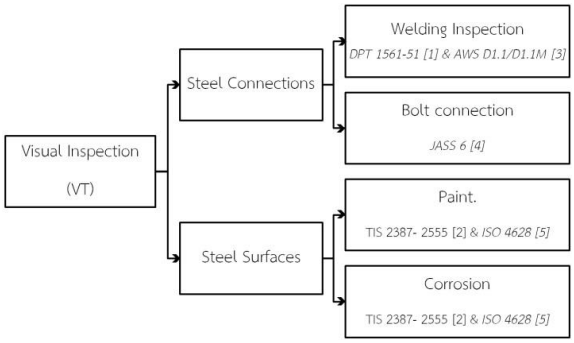

Fig. 1 Visual Inspection flow chart

3.2 Maintenance Personnel Interview

Interviewing the maintenance personnel of that structure is a good way to obtain the information about the current situations, problems, and maintenance criteria of the real steel structure. This approach strongly helps on identifying the indirect cause and root cause of the damage and problem of the steel structure in Thailand.

4. Damage and Problem

Site inspection were conducted on a steel structure at different locations and environments to see the difference effects from the external factors such as temperature, humidity, distance from the water source, etc.

4.1 Steel Power Plants

Five power plants in four different regions which are north, east, middle, and south of Thailand were visually inspected. The inspection results show that the steel structure in the power plants located at the north and the middle of Thailand has some minor corrosion on the steel surface. Additionally, the result also found some noticeable deterioration of the steel coating (Paint) due to long usage, such as blistering, flaking, and the change in intensity of color.

4.1.1 Interview Results

The interview of maintenance personnel were performed for each power plant. The results indicated that most of the power plants have the maintenance crew who responsible for the maintenance work. However, each power plant has different maintenance routine, particularly a periodic inspection routine. The inspection routine varies from every year, every two years and every five to ten years or on periodic inspection since it was built.

The maintenance routine is to inspect the structure visually to see the deterioration of steel members, coatings, and connections (Weld and Bolt connection). If there is any major damage on the structure, that section will be replaced. If any corrosion was found, the crew will remove the paint and rust off of the steel surfaces and repaint it. In case of the paint deteriorated, the paint will be removed and repaint afterwards.

4.1.2 Inspection Results

The results from visual inspection on the steel structure in the power plant shows some minor corrosion on the steel surface occurred on every power plant, because of the coating defect.

In addition, more severe damages were found on some power plants due to the problem corresponding to poor maintenance routine and the surrounding environmental condition.

A relationship between damage and maintenance routine can be stated as, “less maintenance cause more damage”. For example, the power plant that maintenance every year will have less damages than the power plant that maintenance every five years accordingly.

Fig. 2 shows a severe corrosion on the steel column in the power plant located on the southern part of Thailand, around 1 kilometer from the sea shore. This power plant has a periodic maintenance every five to ten years, causing the deterioration of the paint and corrosion. According to ISO 4628, that the paint has the degree of blistering of 5(S3), and the degree of rusting of 4(Ri4). Those were considered as severe level of damage.

Fig. 2 Corrosion on the steel column in power plant

Also, the relationship between damage and the environment can be state as, “more severe environment cause more damage”. For example,

the power plant located on the southern part of Thailand will have more corrosion than the one located on the northern part of Thailand.

Fig. 3 and Fig. 4 show severe corrosion at the steel connection of a power plant structures, located on the eastern part of Thailand, around 50 meters from the river mouth. The water in the river was brackish water, which contain high chloride. This caused severe corrosion to the steel structure and the steel connections.

Fig. 3 Corrosion at steel bolt and plate in power plant

Fig. 4 Corrosion at weld of the column in power plant

Lastly, the weld connection and bolt connection of a steel structure in the power plants were acceptable according to the criteria in DPT 1561-51; [1] and AWS D1.1/D1.1M; [3] for welding visual inspection, and JASS 6; [4] for bolting inspection. Since, the steel structures in the power plants were fabricated from the factory, the quality of the welding and bolting connection is good.

4.2 Steel Expressways

Expressways in Thailand are mostly concrete structures, but there are a few expressways that were constructed buy steel due to the lane expansions of expressways.

4.2.1 Interview Results

From interviewing the personnel who responsible for maintenance work of the expressways, inspection routine for the expressways were divided into four types which are;

1. Daily inspection: performing visual inspection in a patrol car, looking for major damage and take photos.
2. Periodic inspection: primary inspection to maintain expressway durability, the frequency of inspection per year depends on the difficulty of the location accessibility, risk and the possibility of structural damage.
3. Special inspection: the additional inspection using more advance testing apart from daily inspection to ensure the safety of the customers.
4. Emergency inspection: a visual inspection after the event of natural disasters or fatal accident on the expressway to initially check the expressway before special inspection to consider emergency repair.

The damage will be divided into four levels, namely “A (Poor Condition)”, “B (Fair Condition)”, “C (Good Condition)” and “D (Very Good Condition)”. The evaluation of damage can be carried out by using photographic reference methods.

4.2.2 Inspection Results

Inspection of steel expressway has to carry out by using patrol car for transportation around the site and parked in the parking zone under the expressways for safety. The result shows that, the expressways in Thailand are in fair condition with some minor damage found on the steel were mostly coating defect due to the deterioration of the paint. Still, there are some expressways that were repainted recently according to the maintenance routine.

For the connection of the steel, both weld and bolt were acceptable according to the criteria in DPT 1561-51; [1] and AWS D1.1/D1.1M; [3] for welding visual inspection, and JASS 6; [4] for bolting inspection. Since the steel structure of the expressways were

fabricated from the factory, the quality of the welding and bolting connection is good.

Fig. 5 Steel expressway with deteriorated coating

Fig. 5 shows the deterioration of coating on steel expressway due to long service life of the coating and the environmental damage.

4.3 Steel Billboards

The steel billboard in Thailand are mostly privately owned, so it is depends on the owner's judgment whether to maintenance it or not. Since steel billboard structure does not have to carry too much load, its maintenance is in low priority. Even though, recently there was an accident of steel billboard collapsing down, caused damage to the surrounding properties.

4.3.1 Inspection Results

The inspection criteria were carried out by using the criteria in DPT 1561-51; [1] and AWS D1.1/D1.1M; [3] for welding visual inspection, and ISO 4628; [4] for paint inspection. The billboard that was inspected is located near the road.

The results indicate many serious damages and defects of the welding that affect the capacity of the welding, such as undercut, porosity, and incomplete fusion. Also, some noticeable paint defects such as flaking (S4 to S5) and blistering (S3 to S4), as well as corrosion on the surface of the steel which has the degree of rusting ranging from Ri3 to Ri5.

Fig. 6 shows the defect called "undercut" which is one of the most severe defects for welding connection, because undercutting will decrease the steel sectional area causing a decrease in structural capacities. In this case, the size of undercut is 4.6 millimeters which are unacceptable according to the criteria that in DPT 1561-51, "Undercut shall not exceed 2mm for any length of weld for material equal to or greater than 25mm thick"; [1].

Fig. 6 Undercut at the weld on steel billboard

Apart from the undercut, the welding defects that were clear noticeable are porosity and incomplete fusion (shown in Fig. 7). These types of defect can cause the capacity of the weld to be decrease due to the decreasing of weld area. The criteria for porosity and incomplete fusion in DPT 1565-51 are "Diameter summation of piping porosity which has > 1mm diameter shall not exceed 10mm in each 25mm of weld length for fillet weld" for porosity and "Incomplete fusion is unacceptable for fillet weld"; [2] for incomplete fusion. This, in this case was clearly unacceptable.

Fig. 7 Porosity and incomplete fusion of weld on a steel billboard

4.4 Steel Roof Structures

Even though, roof structure is not the main structure of a building, but every part of the

structure still have to be maintenance to maintain the durability of the structure.

The structure that was inspected in this research was a big concrete building with steel roof structure, the area of these structure covered over 120 square meters.

4.4.1 Interview Results

The results indicated that a priority to maintenance the steel structure itself is neglected since the roof structure is a primary structure that does not have to carry too much load. Also, most of the roof structures have not been maintenance since it was built. The roof structure was constructed at the site by welding with poor quality control.

4.4.2 Inspection Results

Since, the structure that was inspected is very big, so the inspection was carried out "section by section", covering around 25 percent of the whole structures. Because of the difficult accessibility of the location and poor illumination, the welding inspection and paint inspection are impracticable.

The first site is an old building over 20 years old that has never been maintenance or inspection activity since it was built. The result shows that, the quality of the connection (all weld connection) was poor and damaged, caused by welding procedure, such as slag, burning point or hole on the steel section, and the melted or cut spot on the steel sections as shown in Fig. 8.

Fig. 8 Missing steel section melted by poor welding procedure

The second site is a roof structure of a convention hall, constructed by steel pipe with weld connection. The result shows that, some of the weld connections were constructed poorly, as shown in Fig. 9.

Fig. 9 Discontinuity of weld on steel pipe roof structure

Moreover, many signs of poor construction were found, such as incomplete welding, poor installation, and poor welding.

Fig. 10 shows the incomplete welding of the beam girder (over 40% of the weld was missing).

Fig. 10 Missing weld on steel beam girder

4.5 Steel structures

A simple welded steel structure (shown in Fig. 11) that was built in 2014 was thoroughly inspected based on DPT 1561-51; [1] visual inspection criteria and evaluated based on four types of welding defect, which are crack, undercut, porosity, and convexity similarly to the billboard inspection.

Fig. 11 Welded steel structure

4.5.1 Inspection Results

Since, this structure was recently built and did not locate in a severe environment, so the coating of this structure is still acceptable. The inspection was focused on beam-column welded connection. The results obtained from inspecting 12 beam-column joints which contained 64 of welds that has defects.

The result shows that the majority of the welds had defect on the surface, especially convexity and undercut, which exceed the standard limit in DPT 1561-51; [1]. The evaluation of the weld defect was classified as "unacceptable", and the percentage of the welds that was unacceptable for this site is showing in Fig. 12.

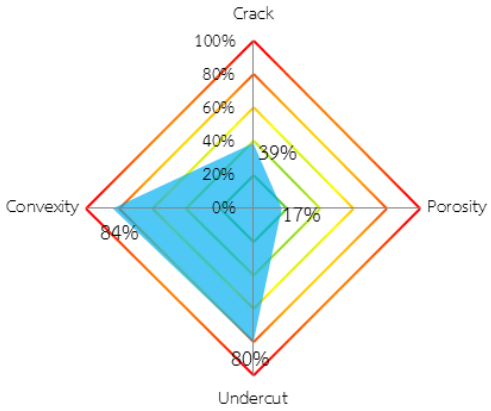

Fig. 12 Amount of welding defect found on 64 of welds (in %)

From the inspection results, it concluded that the defect of the welding came from poor workmanship because of the welding procedure. Therefore, it is clear that this site has not done any welding inspection according to the Thailand standard.

Fig. 13 shows the welding defect found at the beam-column joint of a steel structure.

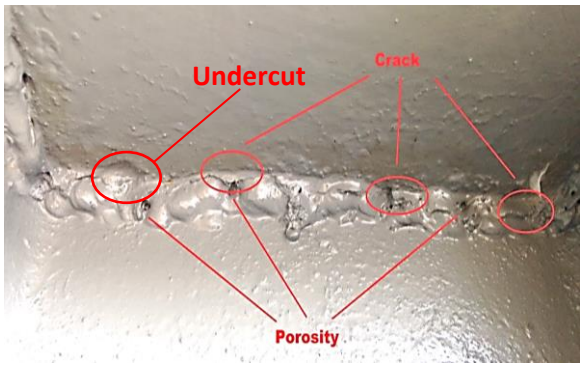

Fig. 13 Welding defect found on beam-column welding connection

5. Indirect cause and root cause of damages and problems

This section talked about the root cause and indirect cause of damage and problem that was found during the research without academic and technical approaches.

5.1 Indirect cause of damage and problem

The results of this research show several damage and defect occurred on the steel structure. This developed from the lack of standard and guideline for maintenance work. If there are standard and guideline that specify a specific time interval for the periodic inspection that the maintenance crew can referred to, the structure will be repaired and protected from the deterioration.

5.2 Root cause of damage and problem

The results of this research show that the problems were developed from poor construction system, and poor workmanship.

5.2.1 Poor or improper material

Quality of the steel material is very important to the structure, as well as the quality of the steel coating. Using poor material could cause a low capacity of the structure and using improper material could cause a low durability of the structure. Fig. 3 and Fig. 4 show that severe corrosion occurred only on the weld material and the bolt connection not on the main column or beam since the material of weld and bolt was different from the main structure. In the other hand, the structure that uses galvanized steel has more durability of the

structure, leading to less maintenance work in the future.

5.2.2 Poor workmanship

Poorly workmanship is one of the most found problem in this research as show in Fig. 6 to Fig. 10 and Fig. 13. This problem tends to cause more risks and enhance the damages to the structure which also affect the other part of the structure.

Most of the time, this problem occurred during the construction processes since there are many factors that can cause this problem such as unskilled labor (no certificate), poor construction methods, no inspection, and no quality control in practice.

However, workmanship can never be perfect since there are many difficulties in the work process such as the position of the welds (over-head welding position in practice is very difficult). As a result, the welding product from the difficult position will never be as good as the welds produce by normal welding position.

6. Suggestion of solutions

The suggestion of solution for these problems can be divided into two approaches which are;

6.1 Maintenance approach

6.1.1 Standards and Guidelines

Maintenance approach of solving the problems is to draft a standard or guideline for the engineer to follow in their work, such as the inspection, evaluation, and repair standard or guideline for steel structure.

The standard should specify the inspection criteria (base on type of damage), evaluation criteria (base on the severity of damage), repair method for each type and level of damage and all of the equipment specification as well as the requirement of inspector, engineer, and workers.

The guideline should specify the inspection routine procedure and scope, evaluation reference, repair procedure for each type and level of damage, and regularity of inspection.

6.1.2 Workshops and seminars

Occasionally arranging workshops and seminars are a good ways to establish a problem comprehensive and solution for an engineer and anyone who involved with steel structures.

6.2 Construction approach

The construction approach is to prevent the defect that can cause damage to the structure in the future as the root cause of the problem is “poor construction system”.

6.2.1 Construction handbook

The solution is to draft a handbook for an engineer, which specifies a specification for the material, construction methods, and workmanship specification clearly. Therefore, engineer or contractor can follow the proper ways to construct a steel structure. This could relate to the inspection routine in the previous section.

For an example, if the handbook specify the material specification for a power plant such as a minimum steel properties that the contractor should use for the heavy chloride environment, or the properties and thickness of the coating for the steel structure that will be expose in heavy sunlight. The structure durability will be better than the structure that was constructed with any material.

6.2.2 Strength reduction factor for steel

When considering about the material specification, the design specification shall also be considered. Because, when a designer has to designs a structure using poor material or a material that is under spec, the designer shall be able to use those materials. But the structure has to be design and construct properly according to its properties. Since many construction projects construct the structure using imported material which produced base on foreign standard, the properties of those materials may not match Thailand standard specification.

The solution for this problem is to draft a standard or a handbook that specify the “strength reduction factor” for the poor grade of material as specify in BC1 design guide; [6] (which reduce the strength up to 80%). The factor should base on Thailand material standard and strength reduction factor should reduce the design strength of the under specification materials to the proper level, in order to use those materials safely.

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