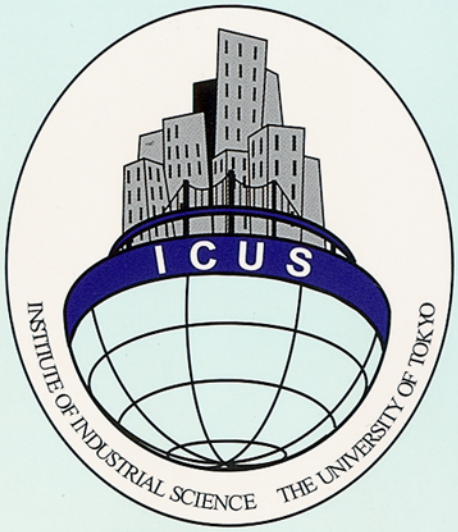
ICUS REPORT 2007-02



INTERNATIONAL CENTER FOR
URBAN SAFETY ENGINEERING

INSTITUTE OF INDUSTRIAL SCIENCE
THE UNIVERSITY OF TOKYO

REPORT ON THE DETERIORATION OF SHORT-SPAN TRAFFIC RC BRIDGES IN BANGKOK METROPOLITAN AREA - A PRELIMINARY STUDY -

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ISBN4-903661-13-X

Serial Number 23

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ICUS Report No. 23

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ICUS Report No.23, July 2007

ABSTRACT

Short-span traffic RC bridges are one of important elements in the traffic system, especially in Bangkok area. Nowadays, in Bangkok alone, there are around 2,000 bridges and these bridges need an appropriate maintenance. In order to establish a maintenance program for these bridges, with limited manpower and financial resources, the information of general conditions of each bridge is very important. Knowing a condition of bridges as well as mostly-found type of deterioration in each area helps persons in charge to make a maintenance plan more efficiently.

This study is a preliminary investigation of short-span traffic bridges in Western Bangkok area (Thonburi Side). Defects, damages, and deteriorations can be observed. It was found that poor construction quality and design without consideration of durability are two main causes of the degradation. Carbonation and sulfate are most widely observable durability problems in this study. Since the area is not in a marine zone, chloride attack is thus not a major problem.

As a preliminary attempt to clarify the condition of the short span bridges, this project was launched. The inspection program is mainly made by visual observation and some basic instruments (for instance, hammer, crack gage, phenolphthalein, etc.) to clarify the type of deterioration. The bridges are then classified based on its condition by newly proposed criteria. By the new criteria, the authors believe that the difference between bridges in different deterioration level can be easily distinguished and the ambiguous of the classification is thus minimized. In addition, the recommended action for each level of deterioration is clearly stated. This classification with the knowledge of type of deterioration of each bridge can be used for the planning of maintenance program for short-span bridges in Bangkok or elsewhere.

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INTRODUCTION

Nowadays, the demand of maintenance work is highly regarded in many developed countries of which most infrastructure has been built long time ago. It appears that now Thailand starts to face the similar demand of maintenance work in order to keep the infrastructure in a good function. The main problem is a lack of systematic method, manpower, as well as budget to do the appropriate maintenance work. The more budget spent on the maintenance activities, the less budget will be available for the expansion of the infrastructure system.

Good maintenance planning can save both manpower and budget. It would be wonderful if we can allocate the budget for the most critical structure and still be able to maintain overall system. In the other words, not only a maintenance planning of a single structure but rather emphasize on the maintenance of entire system should be emphasized. The funding should be spent wisely to ensure that the system works well and to prevent possible problem in the future.

The maintenance of more than 2,000 bridges in Bangkok is not at all easy. Where and how the budget and manpower should be allocated to be most efficient is always questioned. In order to answer the questions, database and understanding of the condition of bridges should be available. In this study, we try to make investigation and to explain the deterioration patterns of concrete bridges by focusing on a smaller group of bridges.

The short-span traffic bridges in Bangkok area which are under control of Bangkok Metropolitan Administration (BMA) are chosen as a sample groups for this investigation. The reason is simple. These bridges are always

received less interest from the responsible agencies and often constructed without good quality control. The bridges on western side can represent a quality of bridges construction and maintenance because its deterioration is not much accelerated by chloride attack. Their characteristics may therefore be extended to other part of Thailand which is not next to sea as well.

The program starts with the visual inspection. The details of deterioration were then collected by sketching as well as photography. Subsequently, the causes and level of deterioration of members is discussed and the data of all bridges is then analyzed in order to rank the deterioration of each bridge into different levels. In this report, general deterioration patterns of short span concrete bridge in Bangkok is described and the classification of deterioration level is newly proposed. The discussion about the condition of concrete bridges in Bangkok is discussed at the end.

1. MAINTENANCE OF TRAFFIC INFRASTRUCTURE IN THAILAND – THE CURRENT SITUATION

Although many mega transportation projects are now during planning process of the government of Thailand, the transportation by private car is still currently the major transportation method of residence in Bangkok. The road and traffic bridges have a very important role for the transportation of Thailand nowadays. As a matter of fact, these bridges are now, more or less, deteriorated. The maintenance of these infrastructures is therefore very importance. In Thailand, the responsibility for the maintenance of the traffic bridges is decentralized to many departments depending on the size and location of the bridges. Following are some of agencies responsible for the maintenance of traffic infrastructure in Thailand.

- Bangkok Metropolitan Administration (BMA)
- Department of Rural Road (DOR)
- Department of Public Works and Country Planning (DPT)
- Department of Highways (DOH)
- Expressway and Rapid Transit Authority of Thailand (ETA)

Because of this decentralized responsibility, maintenance workforce as well as the budget are subsequently split among those agencies. The resources available are not sufficient to run the efficient maintenance program for all these bridges. For instance, the number of officials (excluding teachers) in BMA is about 17,000. Among these personals, 10% of staffs are engineers, 30% are technicians, 50% are skilled labors, and 10% are labors. However, there are about 2,000 bridges under control of BMA. Note that BMA staffs have to take care of safety of buildings in Bangkok area also. It is quite clear that the number of staffs of BMA is not enough to maintain the bridges under its control. The budget of construction and maintenance office (in BMA) was 600 million baht in 2003 and has been increasing approximately 10% per year. This amount is around 25% of

whole BMA budget. However, this budget is very tight and the allocation of this budget is, most of the times, questionable.

Figure 1 and Figure 2 are the records of construction budget and corrective maintenance budget of department of highways (DOH), respectively. The construction budget of DOH has been reduced from 1997 to 2002 while the expense for maintenance of the highways increases rapidly. This fact indicates that amount of maintenance work is increasing remarkably and the construction of new highways is, as the result, limited. Figure 3 shows the allocated budget for maintenance work of the department of rural road (DOR). The budget was raised only once in 2004 and remains constant until 2007 but the amount of road that needs maintenance works increases every year (see Figure 4).

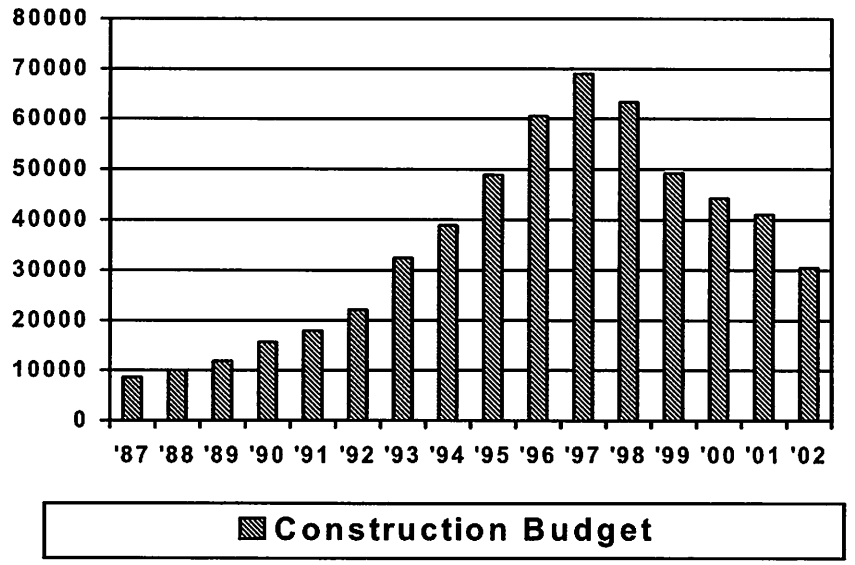

Figure 1: Construction budget of department of highways (DOH)

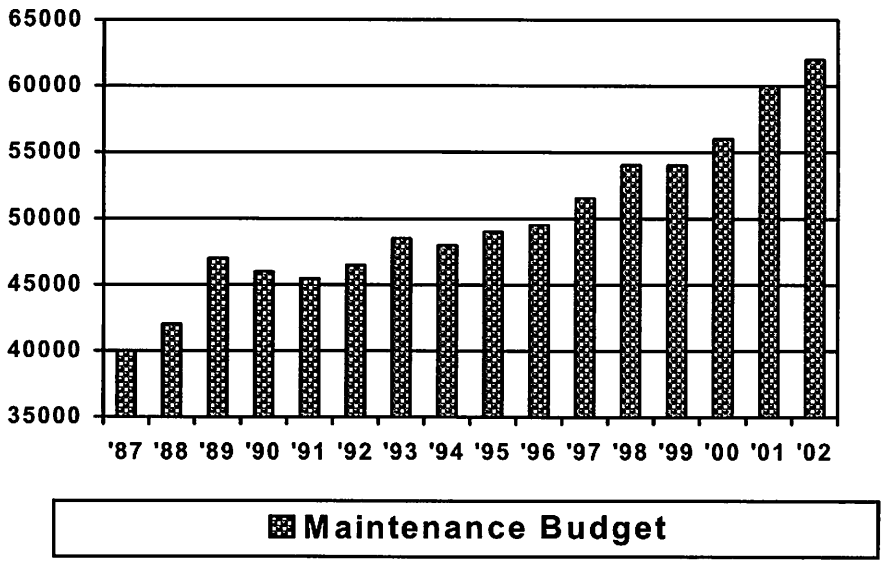

Figure 2: Budget for corrective maintenance of department of highways (DOH)

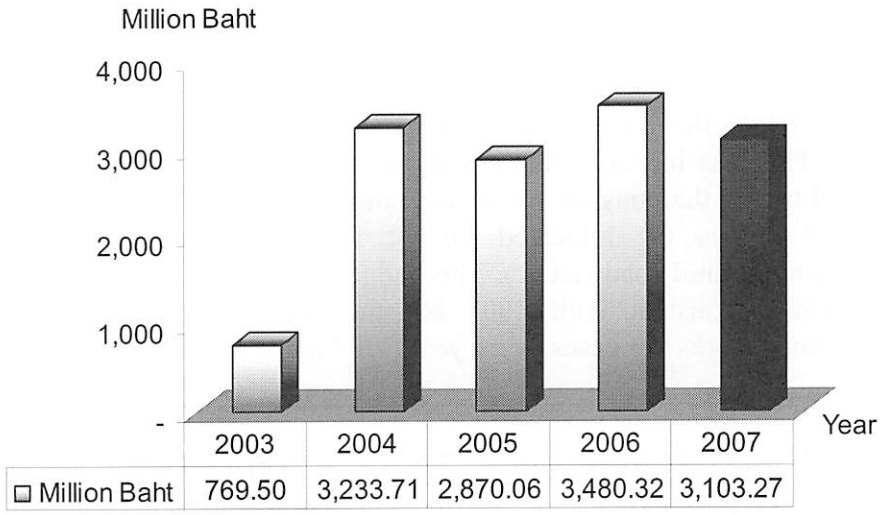

Figure 3: Maintenance budget for rural road (department of rural road)

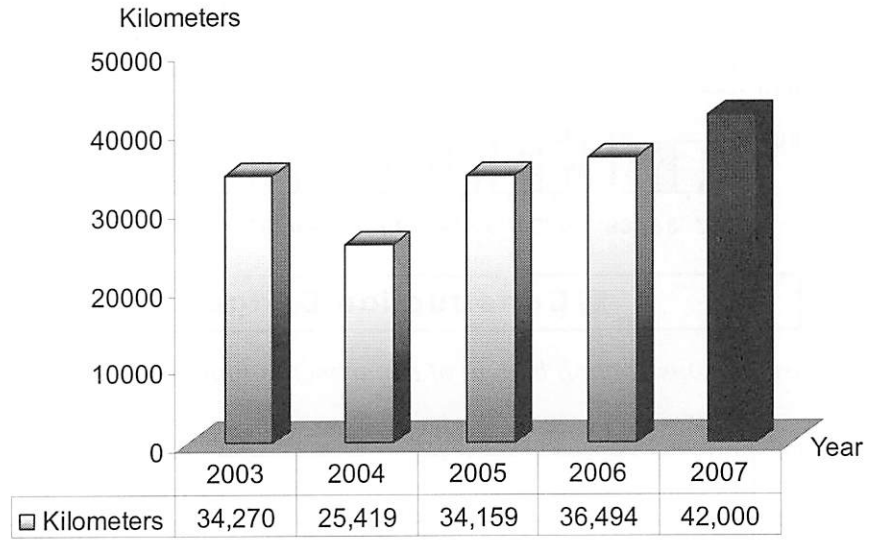

Figure 4: Amount of road requiring maintenance (department of rural road)

The information discussed in this section clearly illustrates that the maintenance work in Thailand is now increasing rapidly but the budget and manpower to do the job is now very limited. Thus it can be concluded that the efficient method to make a condition survey as well as allocation of maintenance budget is a very crucial issue.

2. IMPORTANT OF THE SHORT-SPAN TRAFFIC BRIDGE IN BANGKOK AND THEIR MAINTENANCE

There are around 2,000 bridges which are under the responsibility of BMA. These bridges can be classified as flyovers, pedestrian bridges, and canal bridges. Among these bridges, short span traffic bridges across canals are of the largest number.

These short-span traffic bridges play very important role in connecting the traffic system in Bangkok area. They have, however, received very little concern about their conditions and deteriorations since most of the maintenance budget is usually allocated for the major long-span bridges like Rama IX Bridge (the largest cable suspended bridge of Thailand), Rama VIII Bridge (the asymmetric cable suspended bridge), etc. As the results, some of the short-span traffic bridges which were mostly constructed 30 – 50 years undergo the degradation and there has been no attempt to collect any information about their conditions.

While the economic impact or loss caused by malfunction of any of these short-span bridges is comparatively small when compared with the probable impact from failure of any major long-span bridge, it is expectable that the way of living of most Bangkok residents will surely be disturbed significantly. This will cause an undesirable social impact.

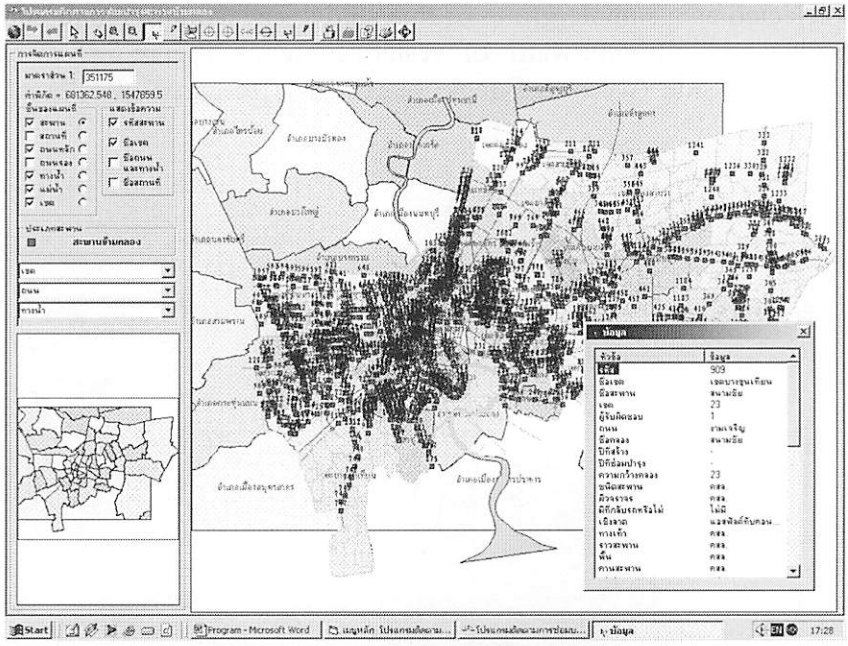

Figure 5: Database of bridges under control of BMA [1]

In fact, an efficient budget allocation for the maintenance of these short-span bridges is a complicated agenda comparing to the determination of structural capacity or the judgment of requirement for repair work of any individual structure. Responsible officers must make sure that the limited maintenance budget is wisely spent for the critical bridges. In order to do so, the database of bridges in Bangkok [1] has been developed (see Figure 5). The database covers the various types of bridges and contains basic information of bridges; however, the updated deterioration of each bridge is not available. It is not here that there are also some studies on the maintenance and deterioration of bridge in Bangkok [2 - 4].

In order to make an efficient maintenance planning for large group of bridges, the basic information on the condition of each bridge is indispensable. Surprisingly, there has been no systematic investigation of

large groups of these bridges. In order to alleviate a severity of the aforementioned situation, this study is initiated as a pilot project of the investigation on the short-span traffic bridges. The concept of this inspection is that it should be extensible to the inspection of the short-span traffic bridges in Bangkok yet the information obtained should be meaningful to the decision-making process.

The study focuses on the visual inspection on the samples since complicated inspection technique does not suit the concept of this study. It is much more economical that the advanced performance evaluation technique is to be applied to those bridges in a critical condition only.

3. INVESTIGATION PROJECT & METHODOLOGY

The group of short-span bridges locating on the west-side of Bangkok was selected as a sample group of this study. The sample group consists of 72 bridges in 6 different wards of western Bangkok. Figure 6 shows the map of Thonburi Side (western Bangkok) which is the area of interest in this study.

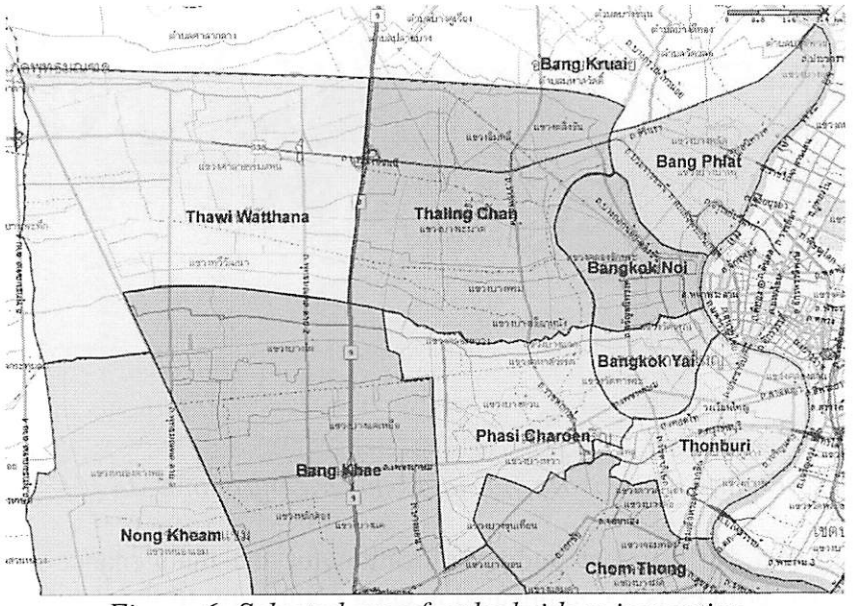

Figure 6: Selected area for the bridges inspection

Figure 7: Location bridges in this study

Figure 7 shows locations of 72 bridges in this inspection program. Since all of these bridges locate in western Bangkok, it is expectable that the chloride penetration on the bridges shall not be the most influential parameters. These bridges are chosen so that their conditions should indicate the nature of short-span traffic bridges in traffic zone. The chloride attack usually governs the deterioration of RC structure in marine environment and thus obstructs the study on the deterioration by other factors.

Table 1: Number of bridges in each road

Name	***Type***	***Number of Bridges***
Charan Sanitwong	Main Road	22
Phetcha Kasem	Main Road	10
Phattha Nakan	Main Road	7
Bang Khun Non	Secondary Rd.	3
Racha Montri	Secondary Rd.	3
Liap Khlong Chonla Prathan	Secondary Rd.	2
Soi Charan Sanitwong 13	Soi	5
Soi Charan Sanitwong 35	Soi	13
Soi Petcha Kasem 48	Soi	1
Soi Petcha Kasem 58	Soi	4
Soi Petcha Kasem 63	Soi	1
Soi Petcha Kasem 88	Soi	1

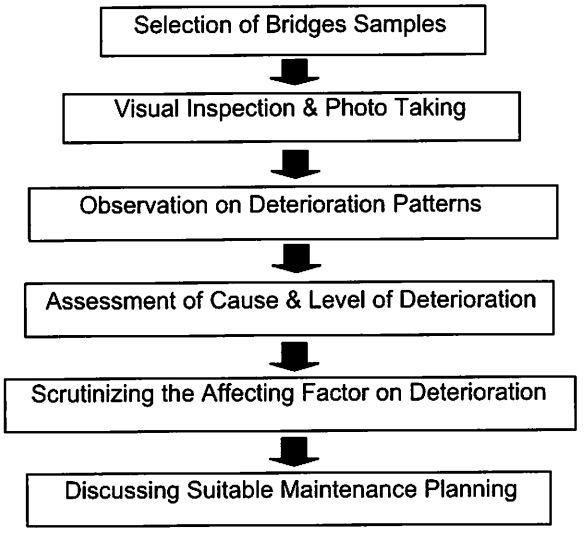

Figure 8: Flowchart of this investigation study

Following are information of the bridges;

- Total Number of Bridges: 72 Bridges
- 3 Main Roads, 3 Secondary Roads, and 6 Soi
- All of these bridges is in Thonburi (West side) of Bangkok

Table 1 gives information of road names and number of bridges to be inspected in each road. The roads are classified into 3 types, namely, main road, secondary road, and soi (smaller road). The traffic intensity is highest in the main road. Figure 8 illustrates the procedure of this study. The final goal of this study is not to establish any maintenance program but rather to point out the important factors that responsible officials should consider about in order to develop an efficient maintenance program. The ACI Guild for making a condition survey of concrete [5] is a reference of this investigation program

4. DETERIORATION PATTERN OBSERVED IN SHORT-SPAN BRIDGES

The deterioration patterns of the short-span traffic bridges are different from those of long-span bridges because of not only different structural systems or different pattern of loading but also the quality of construction work. Hence, it is meaningful to study the deterioration of these short-span bridges so that the appropriate planning can be done accordingly. In this study, it is preferable to classify the damage of each structural members based on its function in order to describe the deterioration each part of the structure.

4.1 Deterioration of Slab

Slabs are directly subjected to the moving load of vehicles, and heavily subjected to drainage water. In this study, it is found that the slabs often undergo more deterioration than beams and columns of the same bridge. Some basic deterioration patterns of concrete slab in short-span concrete bridge are reviewed in this section.

4.1.1 Spalling of concrete surface because of corrosion of reinforcement

The corrosion of reinforcement can be induced by numerous factors. Loss of pH value of concrete is a common factor. Carbonation seems to be the major cause of the corrosion of traffic infrastructure. In the case of slab, especially in the case with improper drainage system, undesirable water from rain drastically accelerates the corrosion of reinforcement.

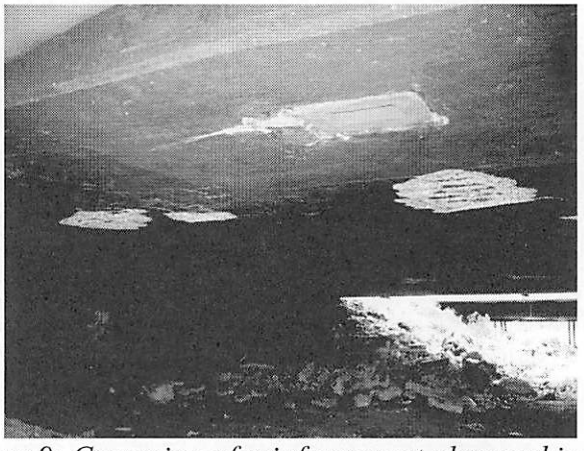

Figure 9: Corrosion of reinforcement observed in slab

Figure 10: Corrosion of reinforcement observed at connection between slab and wall column

Figure 9 shows an example of corrosion of rebar that takes place at the middle of the slab of bridge. It was found that the damaged portion of slab has very thin cover thickness which indicates a poor construction quality. It is also interesting to note the deterioration of concrete around the sewage opening which is also observable in Figure 9. Figure 10 is a clear example

of how water accelerates the corrosion of reinforcement. Corrosion of reinforcement takes place severely at the connection between slab and wall column at which stain caused by rain water could be also clearly observed. It is comprehensible that the leakage of rain water is an accelerator of deterioration process in this case. The corrosion of reinforcement which is accelerated by presence of water can be detected extensively not only in cast-in-place member but also some pre-cast structural elements (see Figure 11). Note that wet surface of structure could be observed clearly although there has been no raining during the period of inspection. The corrosion accelerated by the water can be widely distributed as an example in Figure 12.

Figure 11: Corrosion of reinforcement of precast slab member in traffic bridges

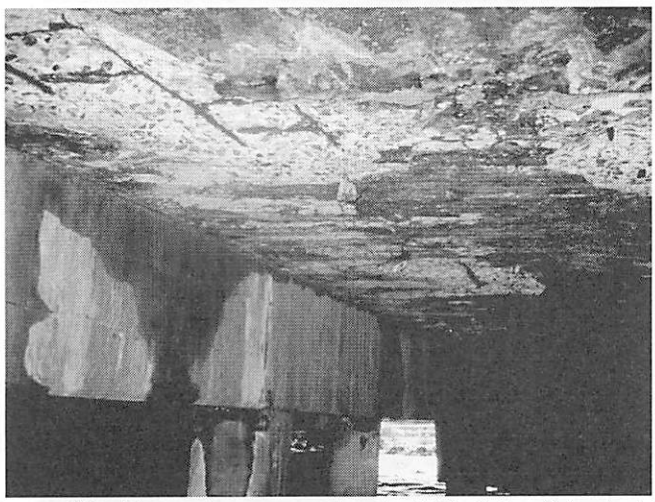

Figure 12: Extensive corrosion in RC slab of the bridge

Figure 13: Corrosion of reinforcement caused by poor construction work

Figure 14: Severe corrosion of reinforcement

Poor construction work is another major factor that possibly allows the reinforcement to be directly exposed to ambient environment. A variety of defects of slab caused by a poor construction work are widely observable in this study. The reinforcement in the badly-constructed structure hence undergo very fast deterioration and, as the result, tremendous loss of cross-sectional area. Figure 13 shows the corrosion that initiated by poor compaction work. When the concrete is not well compacted into formwork, some portion of steel bar will corrode rapidly and will induce spalling of concrete nearby. In the severe case, a large portion of reinforcing bar is exposed to surrounding directly. In this situation, the load carrying capacity of concrete bridge may be drastically reduced below the actual loading and this phenomenon may result in a failure of the bridge. Figure 14 is an example of the structure which is subjected to the corrosion of reinforcement in very risky state.

Figure 15 is another example of noticeable portion of concrete that is likely to be falling down. Similar damaged concrete can be observed in many bridges in this study. Figure 16 shows the corrosion of the structure of

which the concrete cover is extremely small. The very thin concrete cover indicates the error either in design or construction control process.

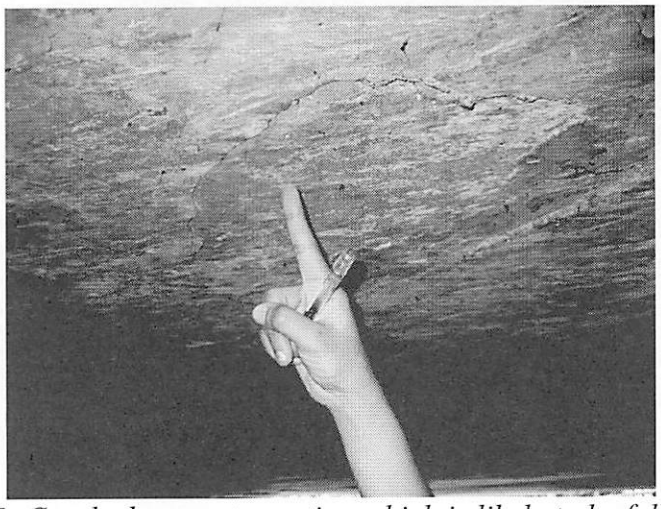

Figure 15: Cracked concrete portion which is likely to be falling down

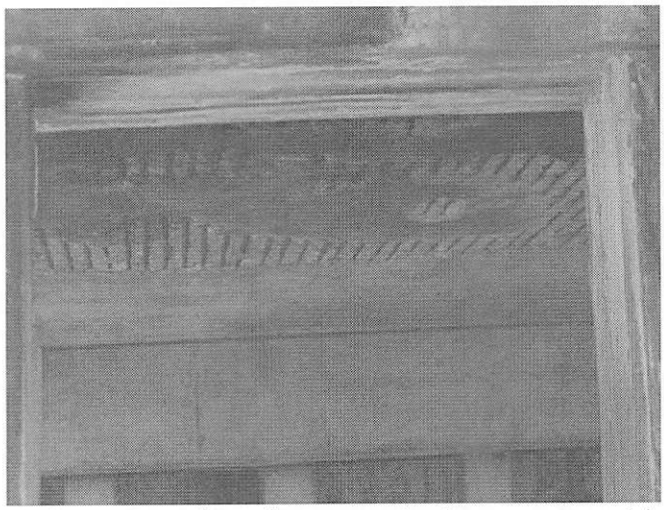

Figure 16: Corrosion of reinforcement in the structure with very thin concrete cover

The level of corrosion can be classified into two different levels. The first one is corrosion that damages merely durability or authentic appearance of structure. The other is the corrosion that severely reduces the cross-sectional area of reinforcing bar so that it may not resist the designed load. An appropriate repair method for each of these cases is different. In the first case that the cross sectional area of reinforcement is not significantly reduced. The structure can be repaired without additional reinforcement. The repair method therefore involves only a cleaning of reinforcement and patching of repair material which can be cement-based or epoxy based. In the other case where the loss of cross sectional area of reinforcement is substantial, the additional reinforcement has to be provided to retain the acceptable safety factor of the structure. The replacement of concrete slab may be another choice in the case of very severe damage. However, the stop of traffic should be also considered in such a case.

4.1.2 Defects caused by poor construction work in slabs

Figure 17 shows another type of imperfection of the construction work which can be observed in some cast-in-place concrete bridge. The rough surface of the structure is caused by the compaction problem or bad mixture of concrete. This imperfection may affect substantially the durability of concrete if reinforcement is located in such area.

In some bridges, the embedment of unwanted, unusual objects inside the slab was found. This problem is mostly found in the cast-in-place concrete bridges. These objects may be pieces or clothes, newspaper, plastic sheet, wood plate, or nail. Sometimes, the object is unbelievably large and the defects may be able to affect the load carrying capacity or durability of the slab significantly like the case in Figure 18 and Figure 19.

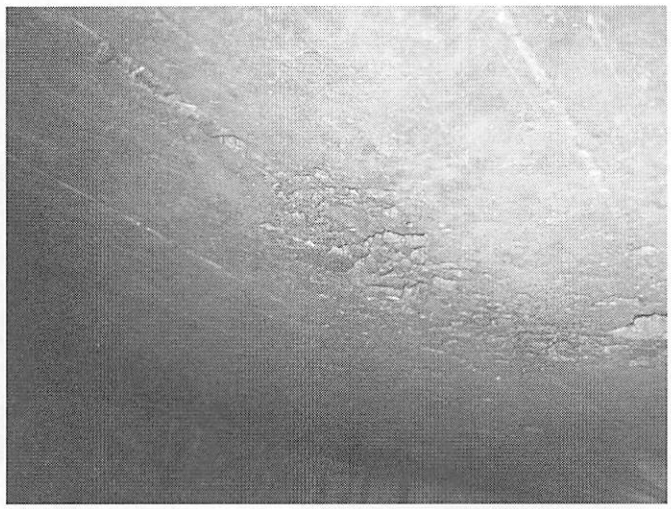

Figure 17: Defects in concrete surface caused by poor construction work

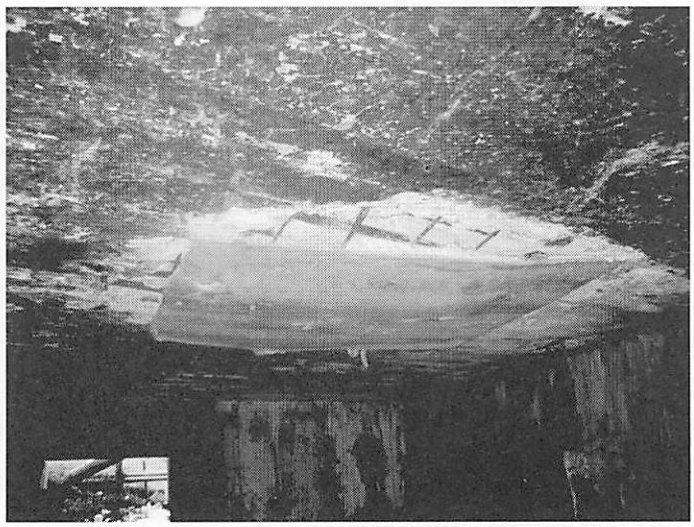

Figure 18: Embedment of wood plate in slab

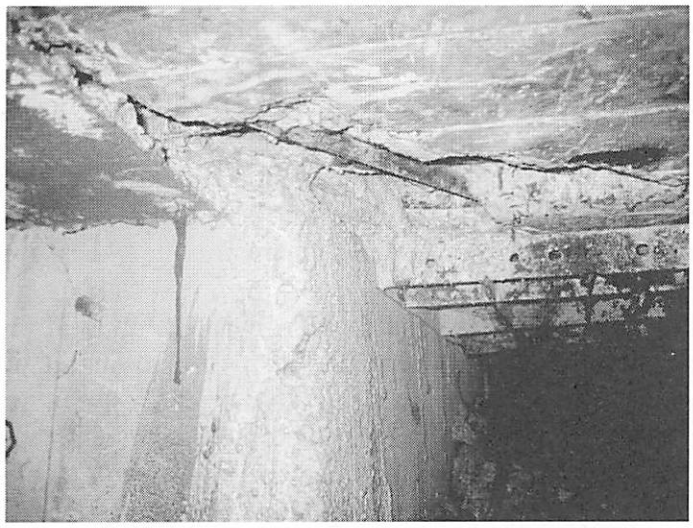

Figure 19: Embedment of steel formwork in the structure

Figure 20: Embedded steel wire in concrete

Figure 21: Embedded steel wire in concrete

Figure 22: Small pieces of wood left in concrete

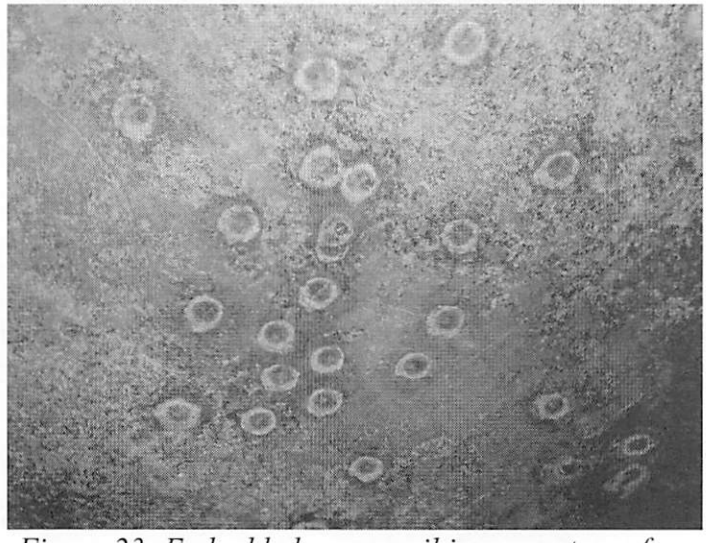

Figure 23: Embedded screw nail in concrete surface

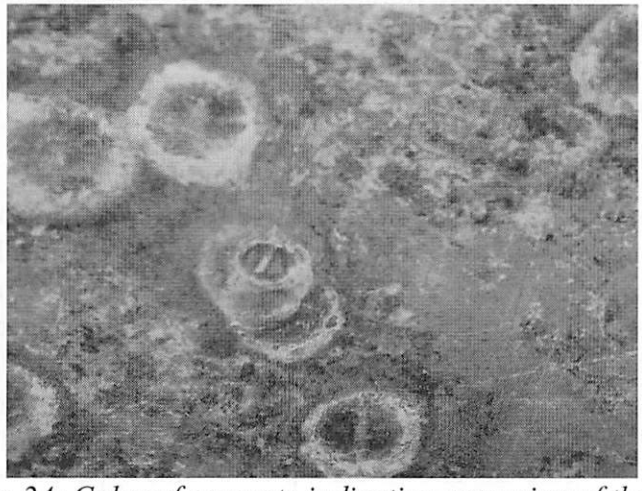

Figure 24: Color of concrete indicating corrosion of the nails

There are also the cases that the embedded object is smaller and may not affect the load carrying capacity of concrete. However, the defect may

not be negligible in the view point of durability. Figure 20 to Figure 22 shows some typical embedded objects which can be easily found in Thailand.

Figure 23 and Figure 24 show special case found in this study. The screw nails were embedded in the concrete. From the condition of concrete, it is expected that the rust is forming on the embedded nail and may cause an awful defects of the concrete surface. Sometimes, steel bars that were used to hold the formwork have not been properly cut (see Figure 25). These steel bars corrode and destroy the quality of the structure. This is another type of bad construction work found in Thailand.

Figure 25: Steel bars for formwork arrangement which were not properly cut after construction

4.2 Deterioration of Structural RC Beams

In this section, damages of beams found in this inspection are discussed. There are several types of beams in these bridges; i.e., floor beam, cab beam, tie beam. The deteriorations of all types of beams are explained in this section.

4.2.1 Breaking of concrete because of friction and unbalance deflection

This type of damage is rare and was found in only a few bridges. This type of breaking happened in the longitudinal beams which are directly subjected to the moving load of vehicles and is caused by the unbalance deflection of adjacent beams together with the friction between them. When these beams subjected to loads the deflection of the beam underneath the wheels of vehicle will deflect more and return to usual deflection when the vehicle has passed. By this effect, the concrete portion between adjacent beams is subjected to the repeated load and hence breaking takes place. Figure 26 and Figure 27 shows examples of this type of damages. It is noticeable that the large portion of concrete has been broken but there is only small corrosion of reinforcing bar. This observation proves that the spalling of concrete is not caused by the corrosion of reinforcing bar. The

repair process for this damage is complicated since it must be ensured that this type of breaking shall not occur again.

Figure 26: Breaking of concrete portion caused by repetitive loading

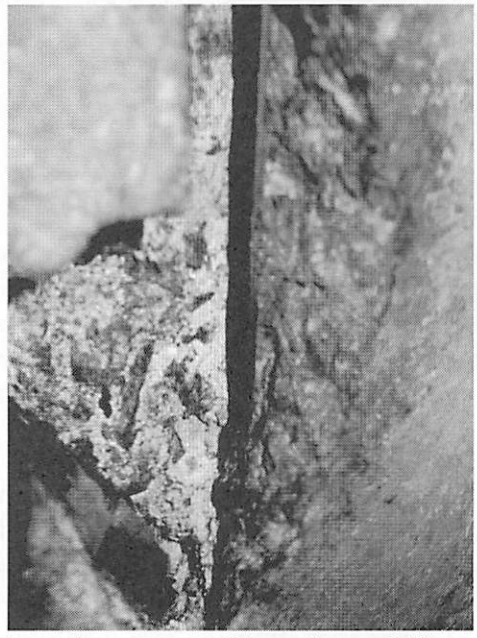

Figure 27: Breaking of concrete taking place while rebar has almost no corrosion

4.2.2 Poor construction work of beams

Figure 28 and Figure 29 show an example of badly-constructed flexural member. The problem is more severe in this case than in the case of slab because most of this defect reduce the area of compressive zone of the member and can thus downgrade the structural capacity significantly.

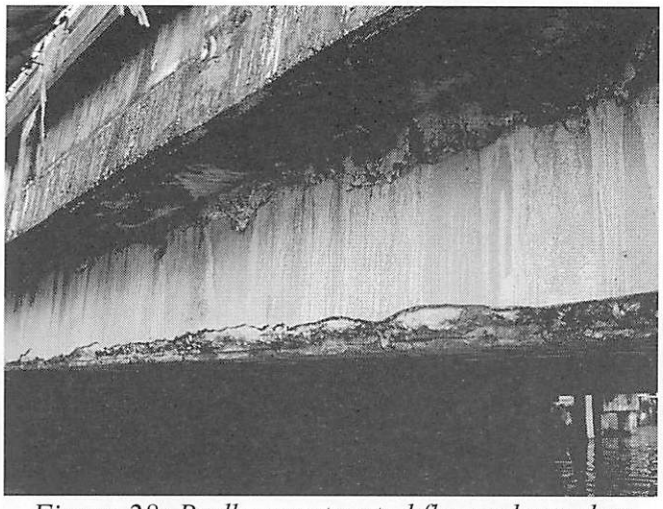

Figure 28: Badly-constructed flexural member

Figure 29: Embedment of unwanted object in flexural member

Figure 30 and Figure 31 show honeycomb in the flexural member found in the inspection. The dangerousness of these defects seems to be more serious than those found in slab. The loss of cross-section in tensile zone of flexural member can change the behavior of the member because of absence of bonding of rebar as well as the fact that rebar is fully exposed to surrounding. The repair work is urgently necessary for this type of defect and the bonding between reparing material with existing rebar should be carefully considered.

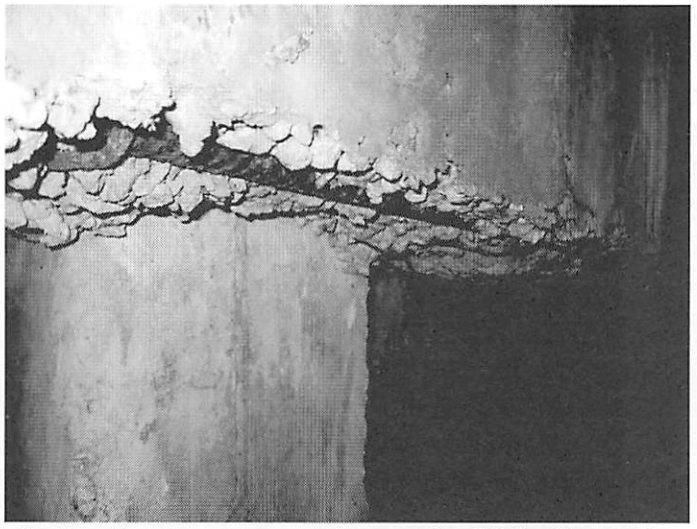

Figure 30: Seriously poor construction work which allow rebar to be fully exposed to environment

Figure 31: Rebar in critical corrosion state because of poor construction work

Figure 32: Longitudinal reinforcement and stirrups losing too much of cross-sectional area

In the case that cross-section of rebar has been almost completely lost (see Figure 32), the replacement of rebar is necessary or the overall structure may fail because of redistribution of load to other members in the very near future. There are also some cases that this honeycomb covers very small area (Figure 33 and Figure 34). However, this defect shall need also patching repair to ensure the serviceability of the structure.

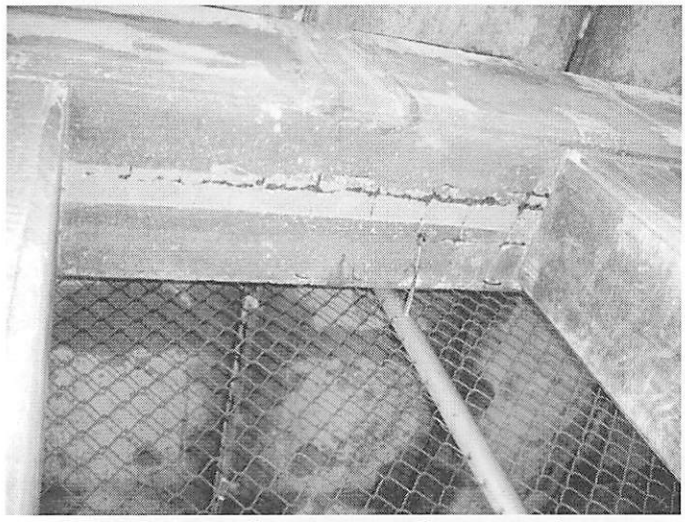

Figure 33: Badly-compacted concrete beams

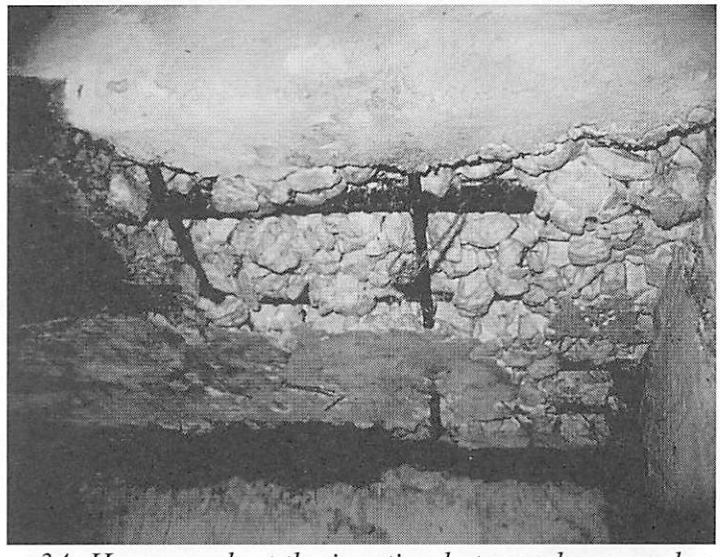

Figure 34: Honeycomb at the junction between beam and column

4.2.3 Deterioration of Cap Beam

Tie beams are transverse members which hold columns together and prevent them from undesirable movement or tilting. Since these tie beams are very close to water, the deterioration due to durability aspects could be extensively observed. The corrosion of reinforcing bar could be noticed extensively. Similar effect from water can be seen as in the case of slab (see Figure 35 to Figure 37).

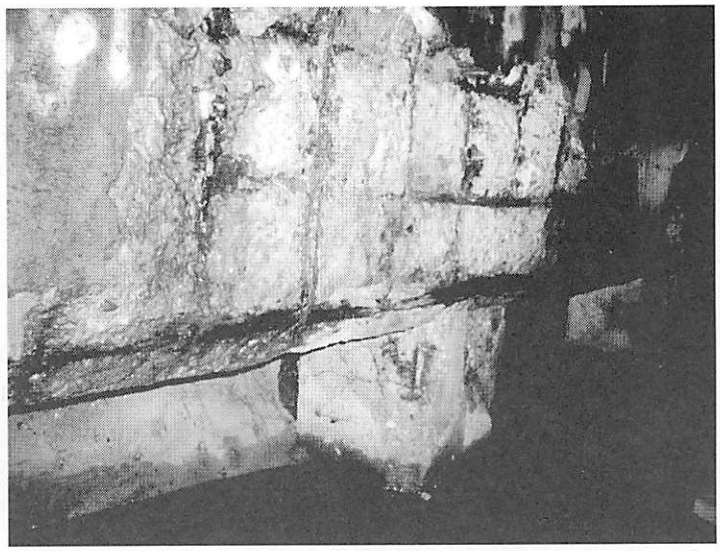

Figure 35: Corrosion and spalling of concrete cover in cab-beam

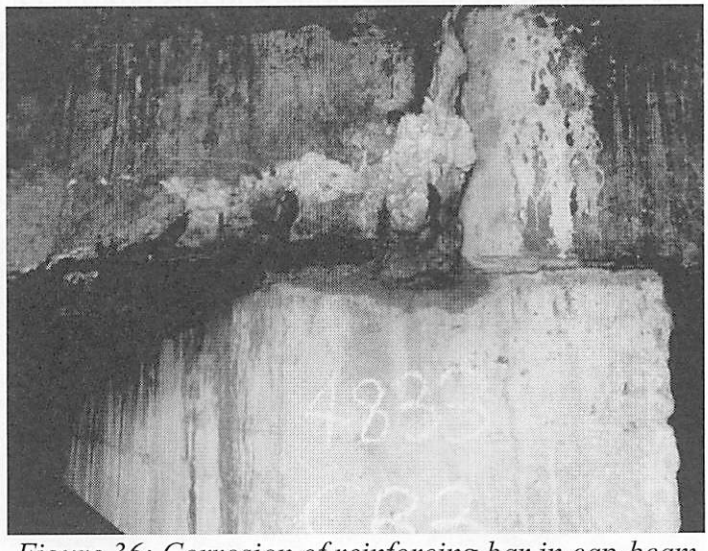

Figure 36: Corrosion of reinforcing bar in cap-beam

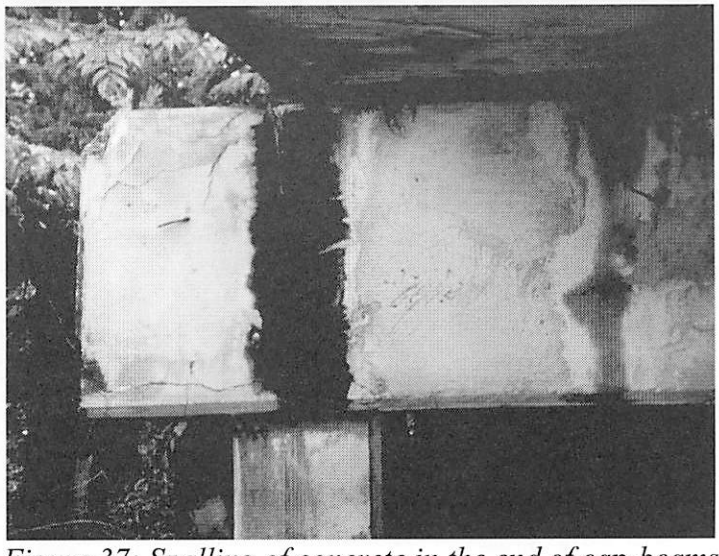

Figure 37: Spalling of concrete in the end of cap-beams

4.3 Deterioration of Columns

Column is a critical structural member. Failure of a single column can cause the failure of entire structure. Also, there are more types of damages that can be observed in column. In this section, the deterioration of columns found in this study is reviewed.

4.3.1 Corrosion of reinforcement in column

The corrosion of reinforcement at the lower part of column can be spotted in this inspection. The lost of cross-sectional area of reinforcement can considerably reduce the structural capacity of the structure. Figure 38 and Figure 39 are examples of corrosion that takes place at the lower end of column.

Some vertical cracks caused by corrosion of vertical reinforcement in columns can be also noticed in many bridges in this project. Figure 40 and Figure 41 are good examples of this type of cracks. It can be expected that these cracks will change into the harmful spalling of concrete cover very soon. These damages should be repaired before getting worse.

Figure 38: Corrosion of reinforcement in the lower part of columns

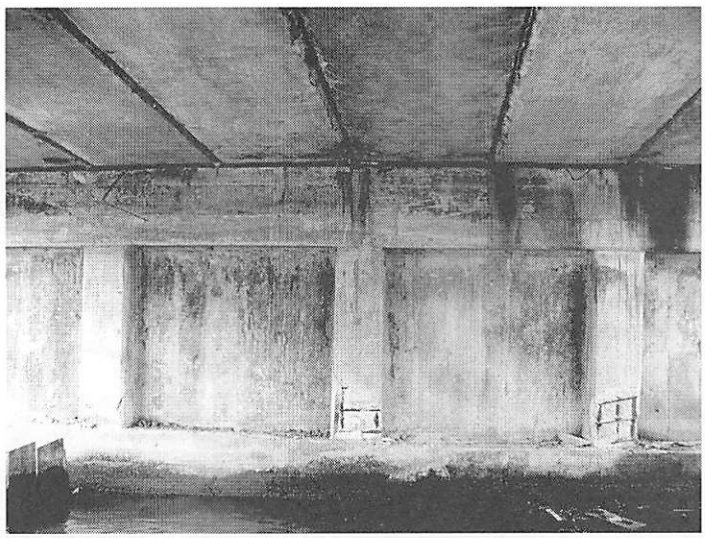

Figure 39: Spalling of concrete in the lower part of columns

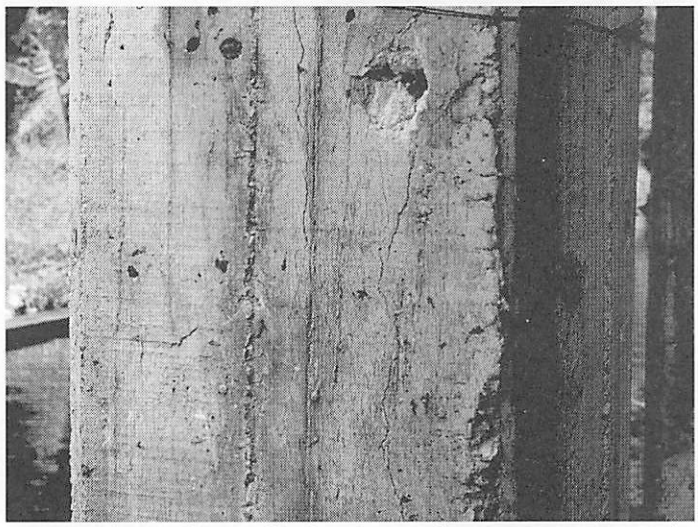

Figure 40: Vertical cracking of RC column due to corrosion of rebar inside

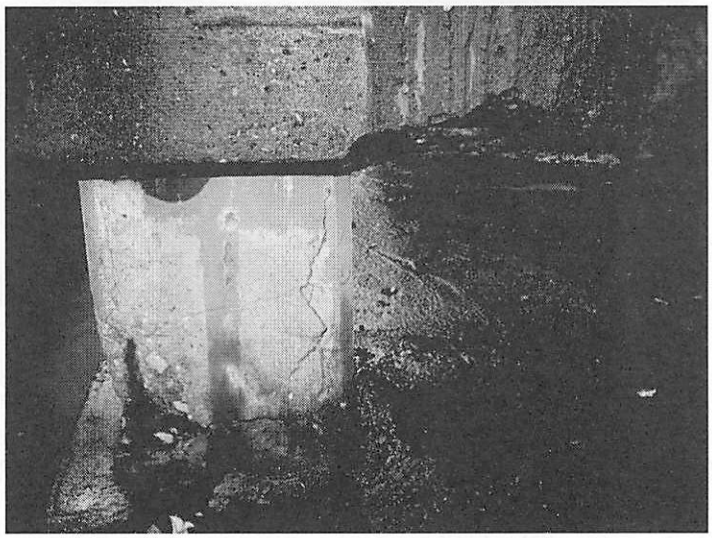

Figure 41: Cracking of concrete along arrangement of reinforcement

4.3.2 Effect of rain water on the deterioration rate of columns

Similar to the case of slab and beams, the portions of columns that exposed to water in some way seems to be subjective to the faster deterioration. An example of such deteriorated portion of column is shown in Figure 42. It is preferable for these portions to be coated by some coatings.

Figure 42: Deterioration and change of color of concrete column

4.3.3 Badly-constructed column

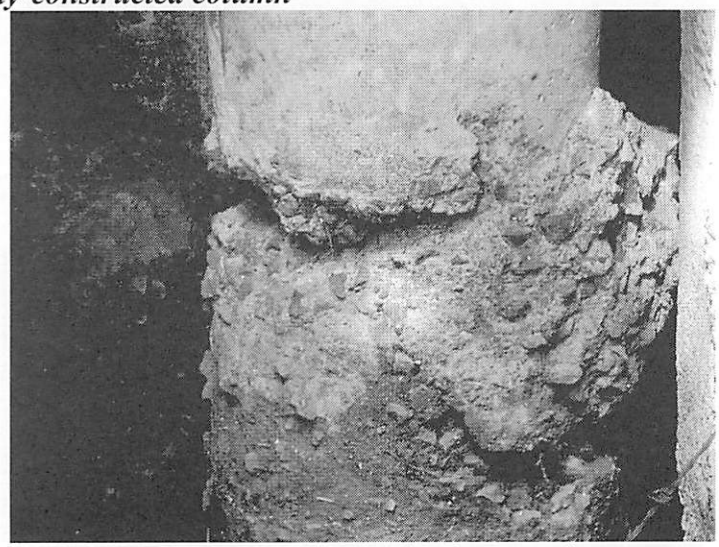

Figure 43: Badly-constructed column under service

Any defects from the poor construction work in column can result in a collapse of the bridges. Unfortunately, many badly-constructed concrete columns have been observed during the inspection. Figure 43 is a clear instance of the construction problem in Thailand. The defects may create unwanted behaviors of the bridge or even a catastrophic failure.

4.3.4 Breaking of column because of unbalance load transfer

Another extensively-found damage of concrete column is the breaking at the head of column (connection between column and cap-beam). The breaking is caused by the unbalance transfer of loading which induces the concentrated overloading on the portion of column. The breaking or cracking then takes place. Figure 44 and Figure 45 shows a typical breaking of column. Figure 46 shows that the breaking of concrete column may happen in many columns in the same bridge.

In some case, the cracking takes place because of badly-constructed column. As can be seen in Figure 47, the connection between column and beam was badly-constructed. Only aggregates exist between column and beams. As the results, the vertical crack formed because of a concentrated load.

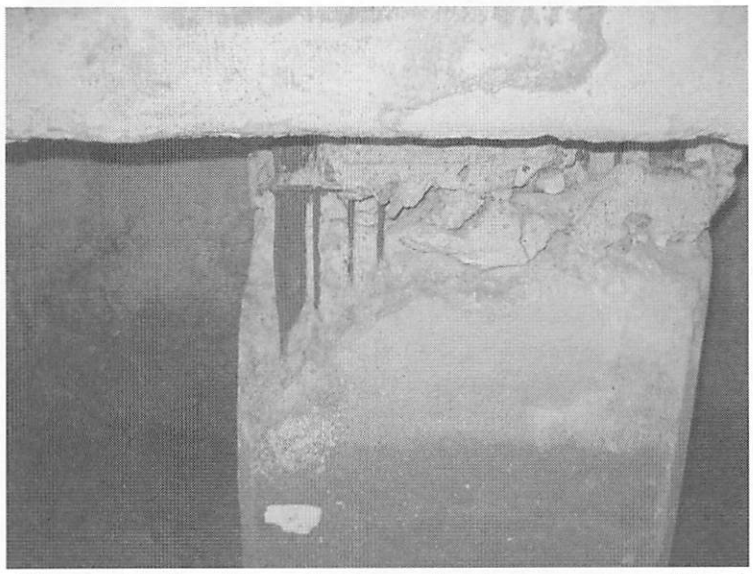

Figure 44: Breaking of column due to concentrated load

Figure 45: Breaking of column due to bad junction

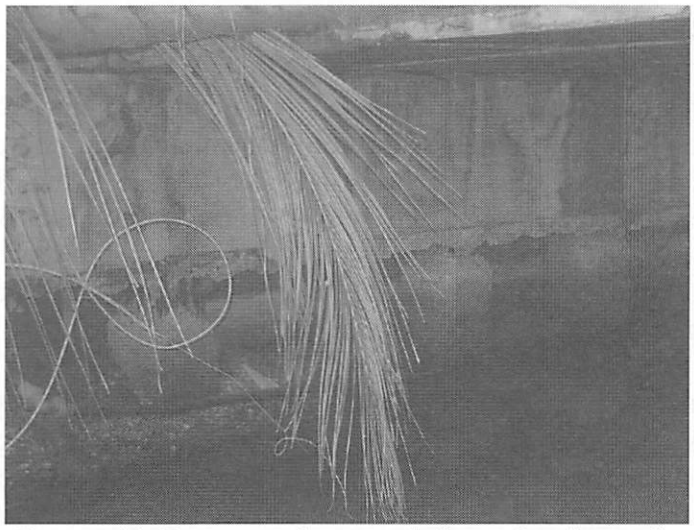

Figure 46: Damages due to unbalance load transfer

Figure 47: Breaking of column due to bad junction

4.3.5 Tilting or bad positioning of column

Some columns of bridges were found tilting or having bad position unintentionally or intentionally. The main reason for this defect is the incorrect position of foundation pile. When the pile is located in a wrong position, misshaped column is build just to link foundation pile with superstructure but it does not possess the required structural performance.

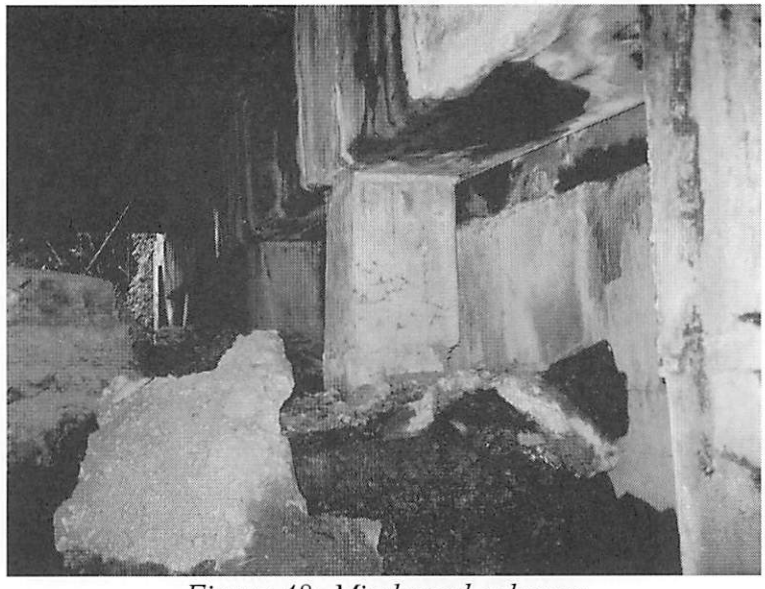

Figure 48: Misshaped columns

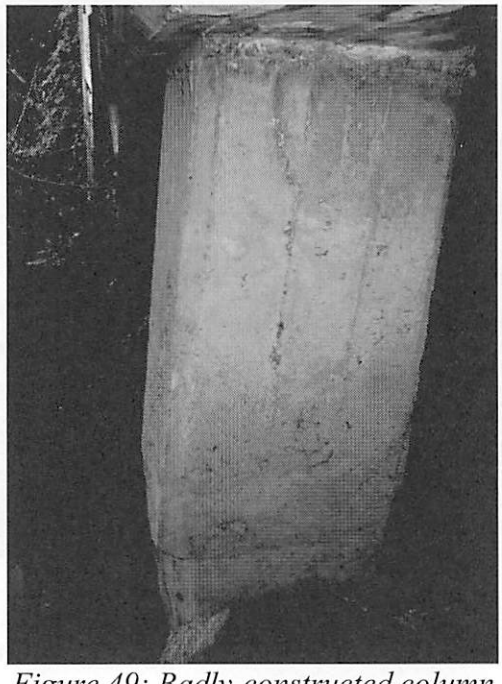

Figure 49: Badly-constructed column

Figure 50: Tilting column

Figure 51: Tilting column

Figure 48 to Figure 51 are some examples of the misshaped column found in this study. Fortunately, there was no observable severe damage in these columns. However, the structural capacities of these columns are surely downgraded by eccentricity and urgent action should be done to confirm a stability of the bridges. In the necessary case, the column may be enlarged to efficiently transfer the load from superstructure to the foundation.

4.3.6 Deterioration of column by sulfate attack

Another problem for canal bridges in Thailand is that the wastewater sewage system is not well designed that some part of the canal is filled with wastewater. This causes the deterioration of column around water level to be damaged by sulfate attack. Examples of columns which are deteriorated by sulfate attack are shown in Figure 52 to Figure 54. It can be clearly

observed that the color of concrete surface has drastically changed and the cement paste has be dissolved so that the aggregate can be seen from outside.

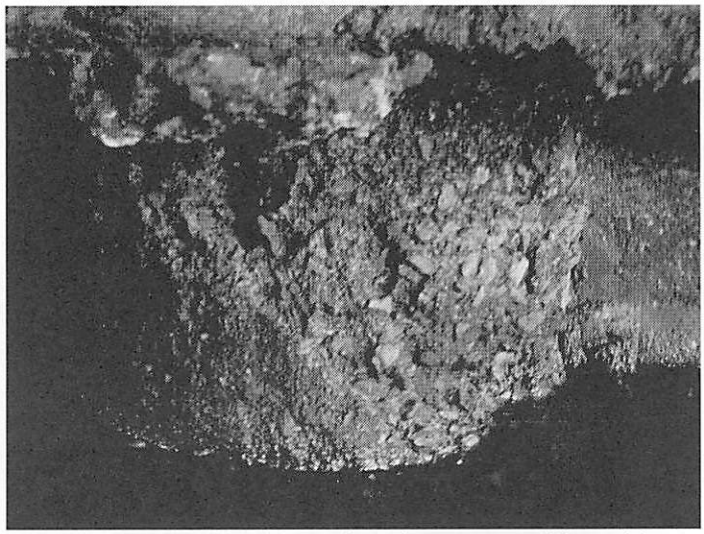

Figure 52: Portion of column that deteriorated by sulfate attack

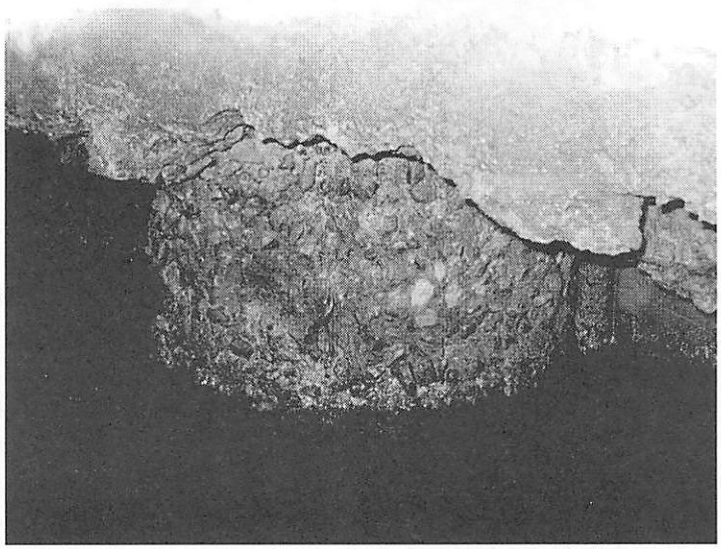

Figure 53: Portion of column that deteriorated by sulfate attack

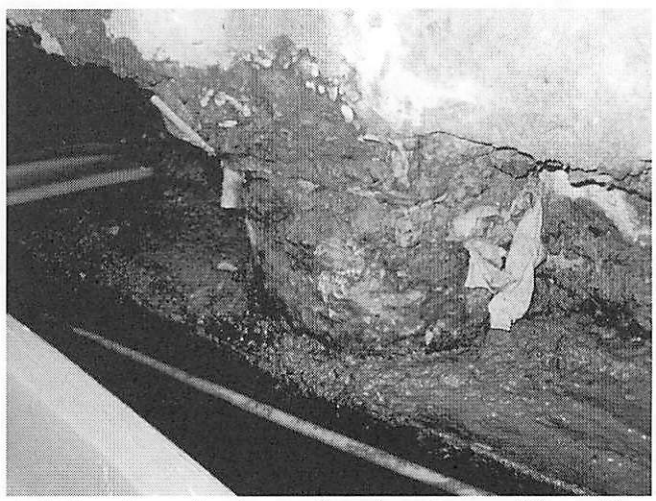

Figure 54: Portion of column that deteriorated by sulfate attack

This problem not only affects the loading capacity of the bridge substantially but also reduces the serviceability and life span of the bridge considerably. This type of deterioration should therefore be controlled properly.

4.3.7 Bad arrangement of Rebar in Column

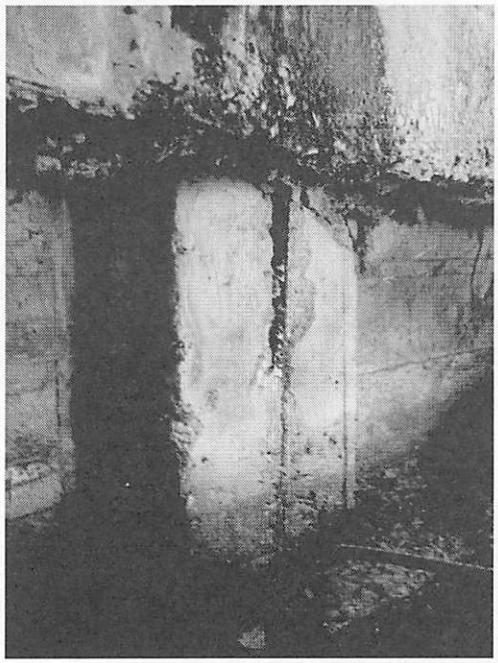

Figure 55: Badly positioned reinforcing bar in RC column

The reinforcement in RC column plays an important role in carrying the service load. Bad arrangement of reinforcing bar in column may downgrade the structural performance of the bridge enormously. The reinforcement can be also buckled if it is located outside shear studs and has very thin concrete cover. The incorrect placement of reinforcing bars in column may induce unbalance of load resisting mechanisms. It was even found that the reinforcement is outside the concrete column in some cases (see Figure 55 and Figure 56).

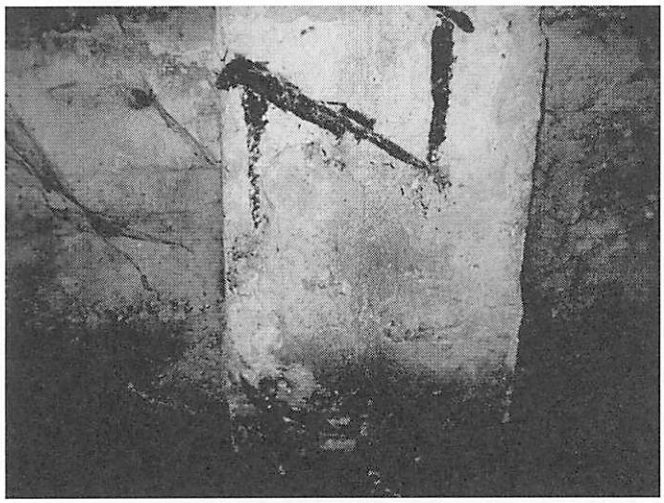

Figure 56: Incorrect placement of reinforcement in RC column

4.4 Deterioration of Walls

Retaining walls are important portion that resist the pressure from surrounding foundation on the bridges. In this study, we found a lot of damages and deterioration of the retaining walls. Those deteriorations are discussed in this section.

4.4.1 Accelerated corrosion by leakage of water

Leakage of water from either adjacent earth fill or from drainage system can harshly create leaching of RC structure and thus accelerate the corrosion. Leaching principally reduce pH value of concrete by dissolving calcium hydroxide [Ca(OH)2] out of concrete and this calcium hydroxide subsequently react with carbondioxide [CO2] and results in calcium carbonate [CaCO3] as a stain of the surface of the wall. Figure 57 and Figure 58 show examples of a stain on the wall.

By lowering pH value of concrete, the possibility of corrosion of reinforcement is boosted. Figure 59 is an example of the wall that reinforcement has been corroded already. After the corrosion takes place, the corrosion is remarkably quickened by the supply of water. Therefore, severe deterioration is usually perceivable in this case. These inspection results indicate the importance of prevention of water from the retaining walls as well as a well-designed drainage system.

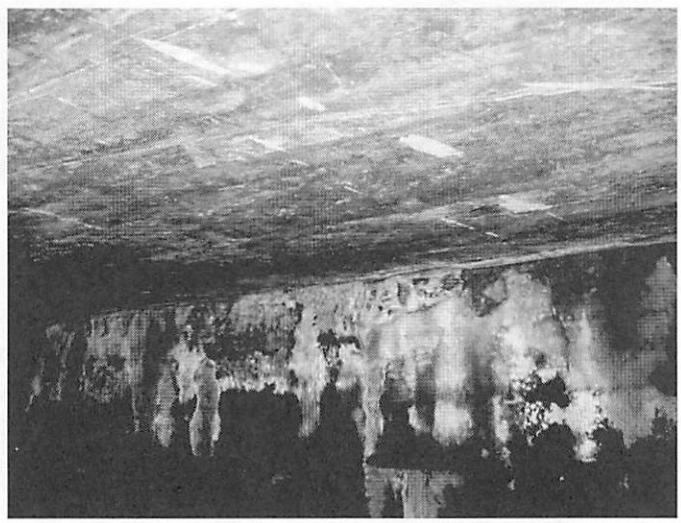

Figure 57: Stain on the surface of concrete wall

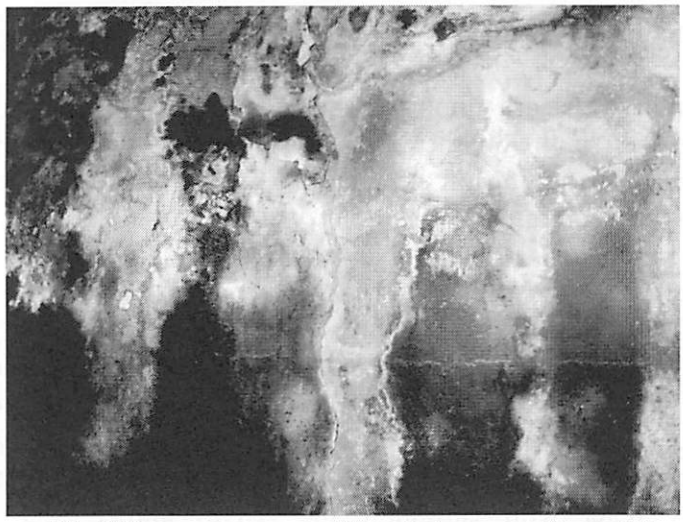

Figure 58: Efflorescence creating stain on surface of the wall

Figure 59: Leakage of water accelerating corrosion of rebar

4.4.2 Damage due to concentrated load of column wall

This type of damage is caused by the force that was non-uniformly transferred from slab and beams. The stress is therefore concentrated in some section and thus the unexpected cracking takes place. Figure 60 and Figure 61 show a column wall that was damaged by this mechanism. This problem can be solved by confirming uniform load transfer.

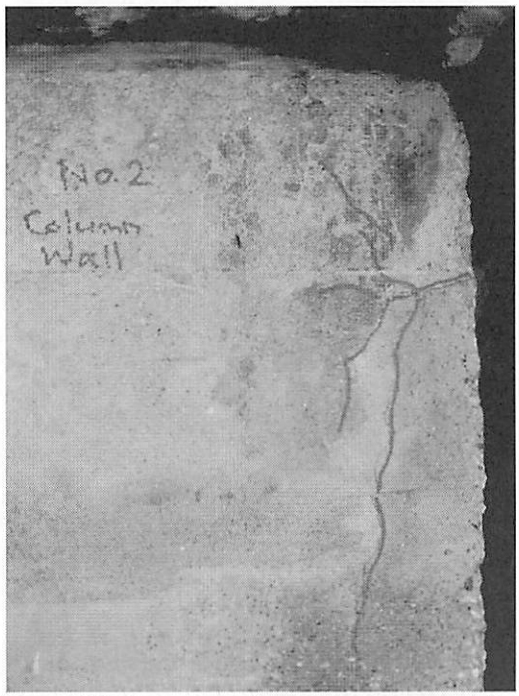

Figure 60: Damage from concentrated load

Figure 61: Damage from concentrated load

4.4.3 Damage of Precast retaining wall RC panels

Main function of retaining wall is to resist lateral earth pressure and prevent a settlement of surrounding wall. If the retaining wall is deteriorated by any process, the bridge may subject to unexpected lateral load which may fail the structure. Figure 62 shows the example of corrosion which may take place in precast RC panels. The corrosion may induce the spalling of concrete and thus create a weak point on the wall and may allow excessive lateral displacement of the wall.

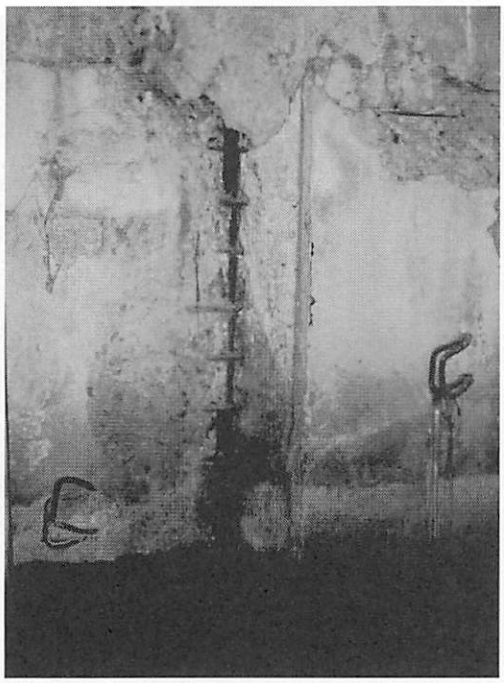

Figure 62: Corrosion of reinforcement in Precast RC panel

Figure 63: Settlement of retaining wall

Figure 63 shows the case where retaining wall is subjected to the overload in vertical direction. The retaining wall has been settled and is now much below the level of bridge. This settlement allows the lateral earth pressure to act on the bridge and the retaining wall fails to resist such loading.

4.5 Deterioration of Tie-Beams

In most of short-span bridges in this inspection project, tie-beams have been provided in order to hold the column together. These tie beams are very near to water surface and are usually subjected to a faster deterioration. The tie-beams are not designed to resist any loads but their deterioration can substantially affect the serviceability of the bridge. Figure 64 to Figure 65 shows a typical deterioration of tie-beams found in this study.

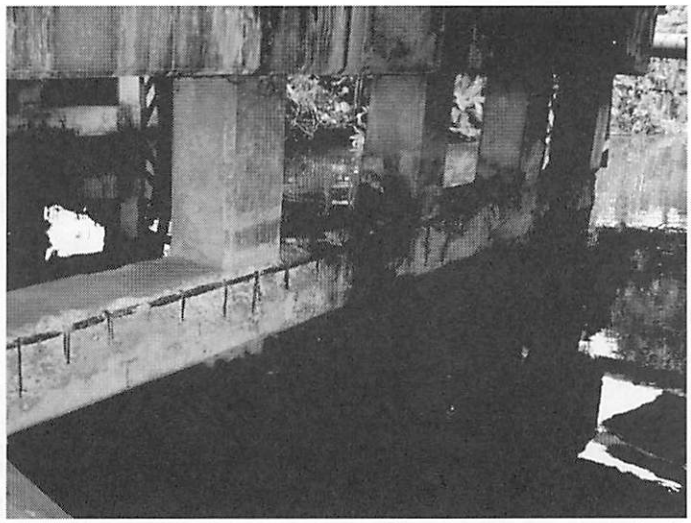

Figure 64: Lost of concrete surface by corrosion of rebar

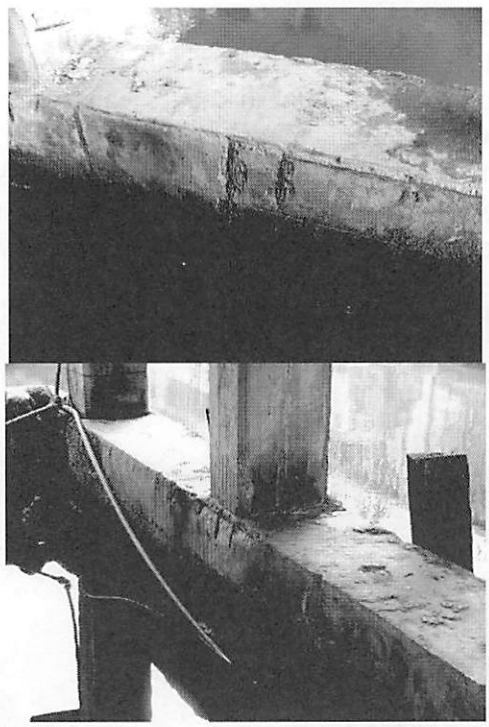

Figure 65: Spalling of concrete and change of color of concrete

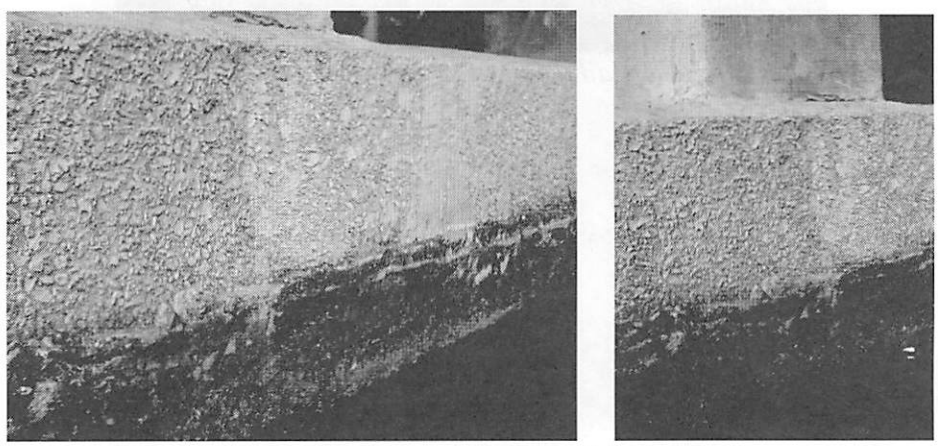

Figure 66: Eroded surface of tie-beams

Figure 64 shows the corrosion of reinforcing bar in tie-beam. It should be noticed that the corrosion takes place more severely in upper rebar. The beam shown in Figure 65 is extensively found. However, the plantation is expected not to have serious effect on the strength or durability. Figure 66 is another typical damage which can be observed in the canal which has been used as transportation route as well. The splashing water from traveling boat speeds up the erosion of concrete surface.

4.6 Structural Failure of Members

In this inspection project, some awful structural failures of members could be found. Fortunately, the structural failure of those members did not cause a catastrophic failure of entire bridge. Examples of those structural failures are shown in this section. Figure 67 shows an appalling failure of column in one of short-span bridges in this inspection project. It is really fortunate that the failure of this column has not induced the failure of the overall structure. The redistribution of load is still not large enough to fail other members. However, the failed member needs urgent repair and probably strengthening work. Some damages caused by uneven settlement could also been observed in this study. Figure 68 is one of good examples. In the deep beam, a few inclined cracks are noticeable (see Figure 68). The damage of the deep beam may not be as critical as one in column shown in Figure 67 but the appropriate analysis is necessary to solve the problem.

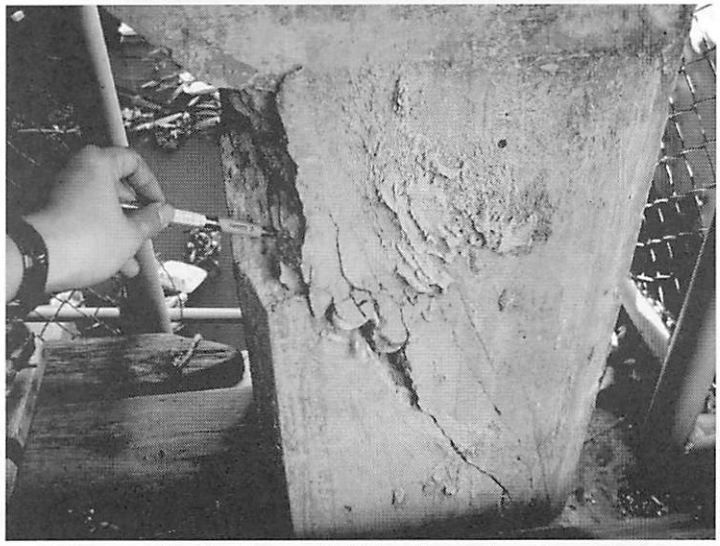

Figure 67: Failure of RC column by shear force

Figure 68: Cracking of deep beam caused by uneven settlement

Figure 69 shows transverse cracks in column. This type of structural damage is rare case. From the observation of the surrounding, it can be concluded that these cracks are caused by the lateral earth pressure and the restrain from the upper slab. These two components result in the bending load on the column and thus induce transverse cracks in the column.

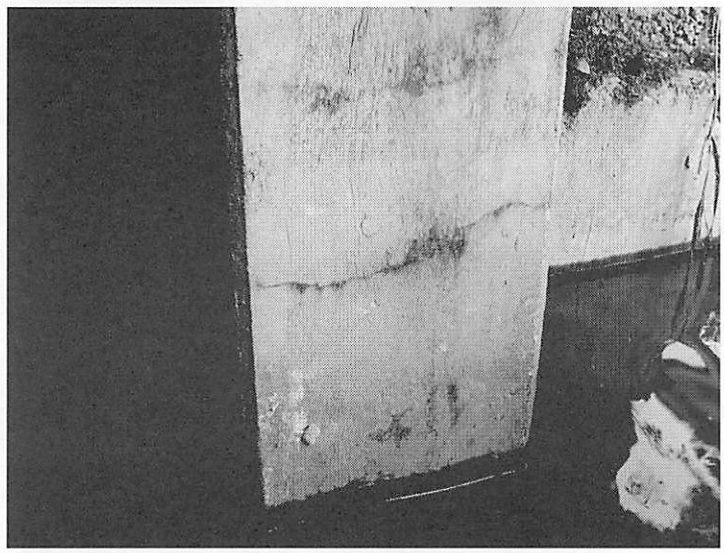

Figure 69: Transverse cracks in column cause by excessive earth pressure

Some minor structural failure can be observed as well, especially at the connection between slab and the column wall or cap beam. Surprisingly, it was found that there is no proper bearing provided in most of the bridges. As the results, the load transfer is concentrated in some areas and creates local cracking in the member. Figure 70 to Figure 72 shows example of the described damages.

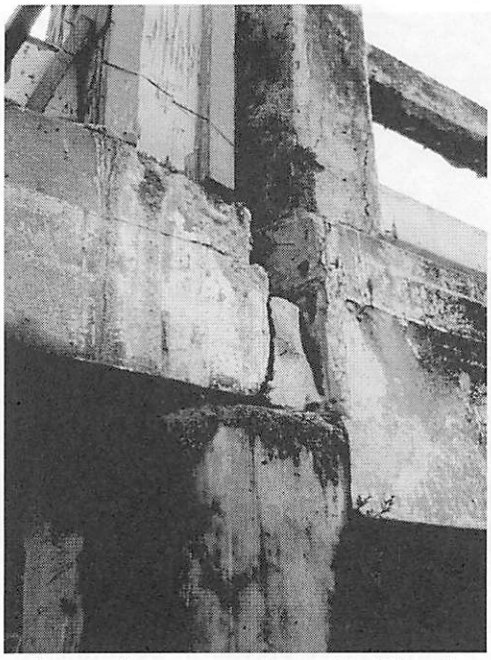

Figure 70: Breaking of concrete due to bad load transfer bearing

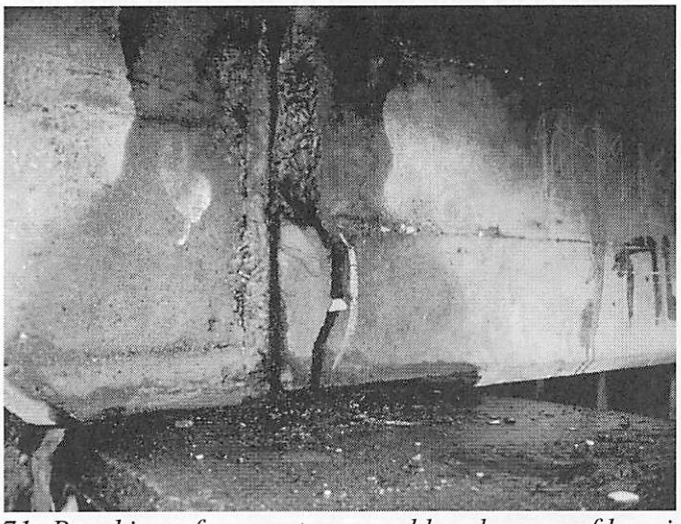

Figure 71: Breaking of concrete caused by absence of bearing plate

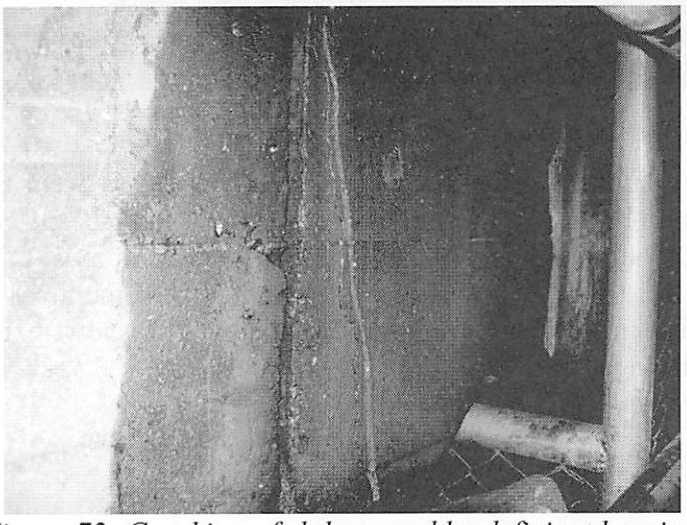

Figure 72: Cracking of slab caused by deficient bearing

4.7 Observed Damages on Repaired Portion

The repaired portion of bridge can be often seen during the inspection of these bridges. However, there are a lot of repaired portion that has repeated deterioration. The most often found cause of deterioration is the inappropriate selection of repairing material. Figure 73 shows an example of usage of repair material with high shrinkage strain. Cracking takes place when repair material shrinks more than its cracking capacity. The portion should then be repaired again by removing the cracked repair material and replace it with a new well-selected repair material.

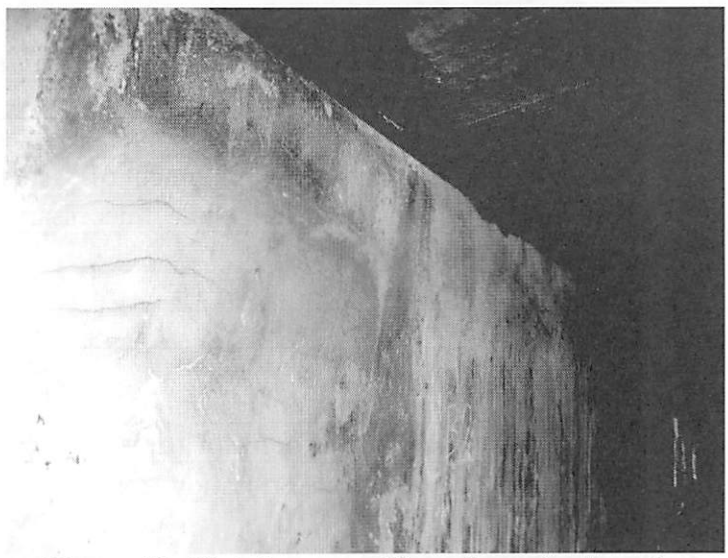

Figure 73: Shrinkage cracking of repaired portion

5. DETERMINATION OF CAUSE OF DETERIORATION AND ITS LEVEL

Determination of type of deterioration as well as the level of deterioration is important information for the maintenance planning of concrete structure. According to ACI Bridge Inspector's Training Manual 90, American Concrete Institute (ACI) recommends the classification of condition of concrete bridges into 10 levels as shown in Table 2. The highest level (level 9) represents the bridge with perfect condition (no deterioration or damage).

Table 2: Classification of concrete quality of concrete bridges (ACI)[6]

Level	Condition of Bridges
Level 0	Failed condition
Level 1	Imminent failure condition
Level 2	Critical condition
Level 3	Serious condition
Level 4	Poor condition
Level 5	Fair condition
Level 6	Satisfactory condition

Level 7	Good condition
Level 8	Very good condition
Level 9	Excellent condition

A similar concept of classification is applied to describe the condition of bridges in this study. However, instead of bridge condition, the deterioration level is concentrated and the number of levels used was reduced in order to increase the applicability of the method. The proposed action for each deterioration level of concrete bridge is shown in Table 3. Examples of deterioration of each level are given in Table 4.

Table 3: Recommended action for each level of deterioration

Level	Recommended action
Level 0	Initial inspection needed
Level 1	Periodic visual inspection with employment of basic tools
Level 2	Detailed investigation needed and repair if necessary
Level 3	Immediate repair obviously needed
Level 4	Strengthening needed
Level 5	Reconstruction needed.

Table 4: Examples of deterioration

Level	Example of deterioration
Level 0	• Structure with no clue of deterioration (for example, cracks, stain, etc) • Structure with no defect (well constructed structured)
Level 1	• Structure with some construction defects which may affect the behavior of the bridge but there is still no deterioration by environmental attack or loading. The detailed investigation should be done to confirm the performance of structure. The structure may show slight change of surface color.
Level 2	• Structure with in which the deterioration by load or environmental attack is activated but not so severe. For example, corrosion crack is already observable but no spalling of concrete, no severe cracking. (corrosion crack width < 0.2 mm) • Structure with change of concrete color or subjected to leakage of water which may accelerated the damage
Level 3	• Spalling or observable large crack (crack width > 0.2 mm)
Level 4	• Cross section of steel much reduced. • Large crack due to insufficient load carrying capacity. • Splitting cracks along the steel • Spalling is observable extensively.
Level 5	• Cross section of reinforcement reduces remarkably. • Severe spalling or cracking • Estimated cost of repair > Reconstruction price

The newly proposed classification method is designed to have two major benefits. The first one is that the difference between each level of deterioration is clarified by reducing number of levels as well as indicating apparent variable and its limit. The second is the proposed level can be linked easily to the action needed. The analysis of the data from this inspection is discussed based on this proposed clarification method.

In order to confirm an understanding of different level of deterioration, some examples of the bridges are shown in this section as an example. Note that all photos in this section are not the photos of bridges in this inspection program. They are used as examples of classification.

5.1 Level 1 Deterioration – Detailed Inspection Suggested

Figure 74 and Figure 75 shows the condition of bridge which will be classified as level 1 deterioration. No terrible damage is observable but the stain of the surface as well as the change of color implies that some parts of the bridges are under deterioration process. It is recommended to protect these bridges whenever the budget is available.

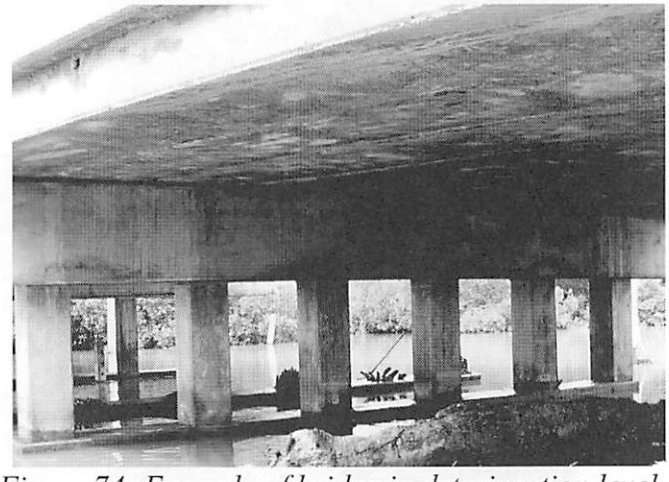

Figure 74: Example of bridge in deterioration level 1

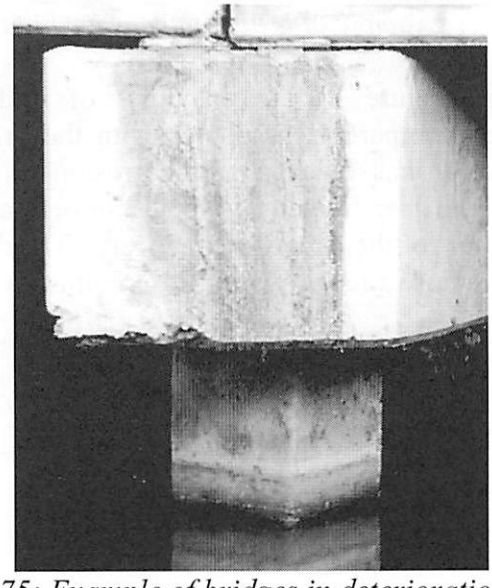

Figure 75: Example of bridges in deterioration level 1

5.2 Level 2 Deterioration - Repair Needed

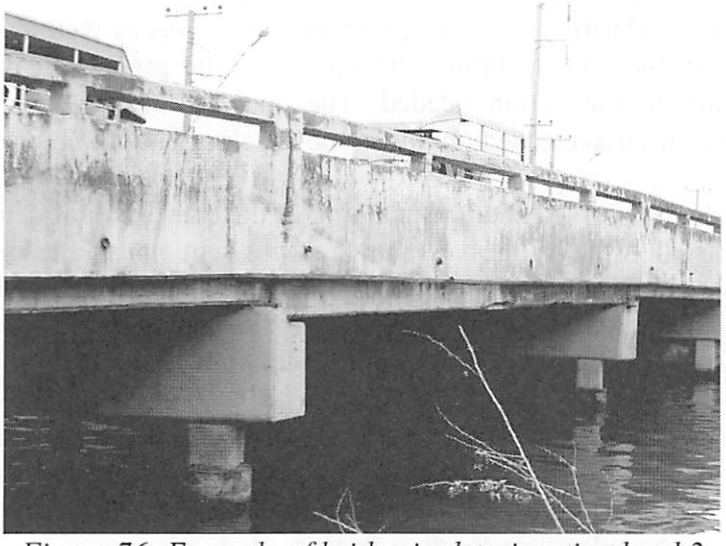

Figure 76: Example of bridge in deterioration level 2

Figure 77: Example of bridge in deterioration level 2

Figure 76 and Figure 77 are examples of bridges with level 2 deteriorations. When compare these photos with the bridges with level 1 deteriorations, it is clear that some signal of corrosion initiation is noticeable in this case (level 2). Either fine crack along reinforcement or red stain of rust is a good indicator for the deterioration level 2. The deterioration due to other causes which require a repair work is also in this level.

5.3 Level 3 Deterioration - Immediate Repair Needed

Figure 78: Example of bridge in deterioration level 3

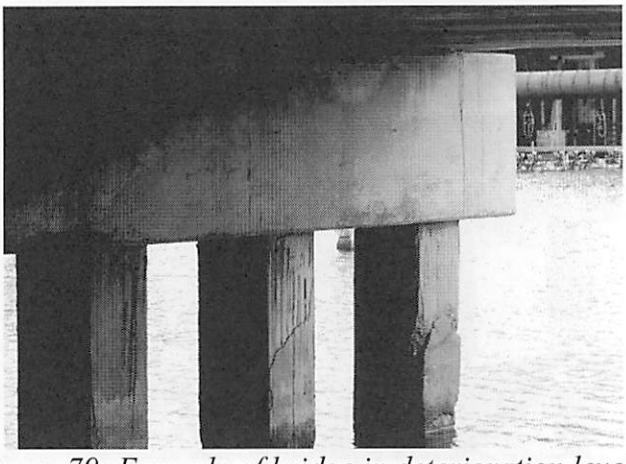

Figure 79: Example of bridge in deterioration level 3

Figure 80: Example of bridge in deterioration level 3

Deterioration level 3 is applied when the structure need the immediate repair (see Figure 78 to Figure 80). Although its loading capacity is not much downgraded, the damage of the bridges in this state is so severe that it will quicken the deterioration and may soon fail the structure. More financial budget will be necessary if the action is too late.

5.4 Level 4 Deterioration – Strengthening Needed

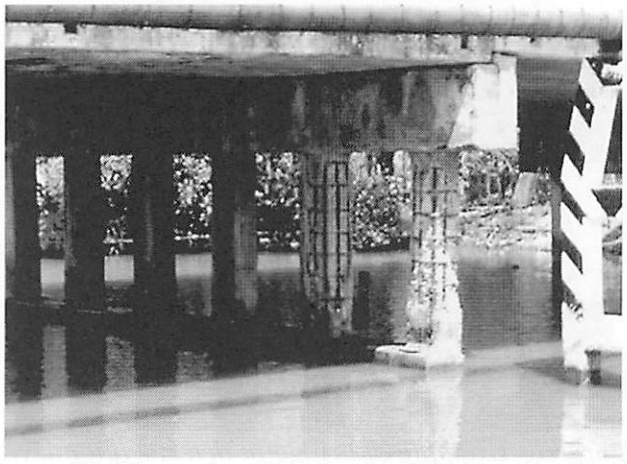

Figure 81: Example of bridge in deterioration level 4

Figure 82: Example of bridge in deterioration level 4

Figure 83: Example of bridge in deterioration level 4

Level 4 deterioration represents the state that the structural capacity of the bridge is substantially destroyed by the deterioration (see Figure 81 to Figure 83). The usage of the structure is risky. In this case, the repair work is not sufficient and the strengthening (for instance, addition of reinforcement) is indispensable and should be done as soon as possible.

5.5 Level 5 Deterioration – Reconstruction Needed

Figure 84: Example of bridge in deterioration level 5

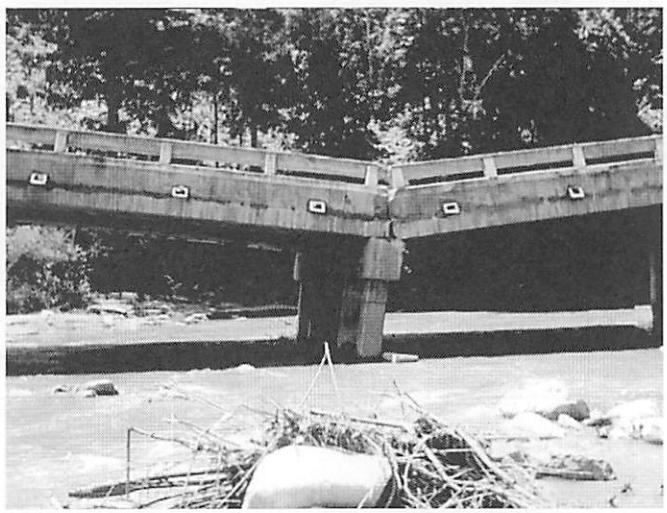

Figure 85: Example of bridge in deterioration level 5

The deterioration level 5 means the state of bridges of which the usage must be suspended and it is not financially reasonable to make a repair or strengthening work (see Figure 84 and Figure 85). The reconstruction is a solution. Absolutely, the bridge should be taken care of before its deterioration reaches this state. The bridges in this level 5 indicates the worst maintenance management of the responsible agencies.

6. STATISTIC OF INSPECTED BRIDGES

Table 5 shows the number of bridges in each level of deterioration. According to the investigation data, 75% of bridges in the sample group need at least an inspection in detail and around 40% need urgent action. This number is higher than usual expectation. Most of the bridges require repair works while the maintenance budget is limited. Of course, the urgent attention should be paid to the bridge with level 4 and level 3 deteriorations. The maintenance budget for bridges with lower deterioration level should be prepared also whenever possible. The action when the deterioration is not severe is much cheaper and less time-consuming. Luckily, we found no bridge with level 5 deterioration.

Table 5: Number of bridges with each deterioration level in each road

Road	***Deterioration Level***					
	1	*2*	*3*	*4*	*5*	*N/A*
Charan Sanit Wong	9	10	2	0	0	1
Phetcha Kasem	2	2	4	2	0	0
Phat Thana Kan	0	0	3	4	0	0
Bang Khun Non	0	2	1	0	0	0
Ratcha Montri	0	0	1	2	0	0
Liap Khlong Phasi Charoen	0	1	1	0	0	0
Soi Charan Sanit Wong 13	1	3	1	0	0	0
Soi Charan Sanit Wong 35	6	5	1	1	0	0
Soi Petcha Kasem 48	0	0	0	1	0	0
Soi Petcha Kasem 58	0	0	3	1	0	0
Soi Petcha Kasem 63	0	0	0	1	0	0
Soi Petcha Kasem 88	0	0	0	1	0	0
All	18	23	17	13	0	1
Percentage	25.0	31.9	23.6	18.1	0	1.4

Another observation which should be drawn to the attention is the distribution of damage. Figure 86 shows the comparison of the deterioration level of bridges in two different areas; namely, Petcha Kasem road (with Phat Thana Kan road and Soi Petcha Kasem 48, 58, 63, and 88) and Charan Sanit Wong road (with Soi Charan Sanit Wong 13 and 35). Most of the bridges in the first group has very serious level of deterioration (level 3 & level 4) while the bridges in the second group was found to be in better condition (mostly in level 1 and level 2). The reason for this difference is still unclear because the information of age, traffic load, as well as construction quality is not available. However, the results show the patterns that the bridges in the same road have similar level of deterioration.

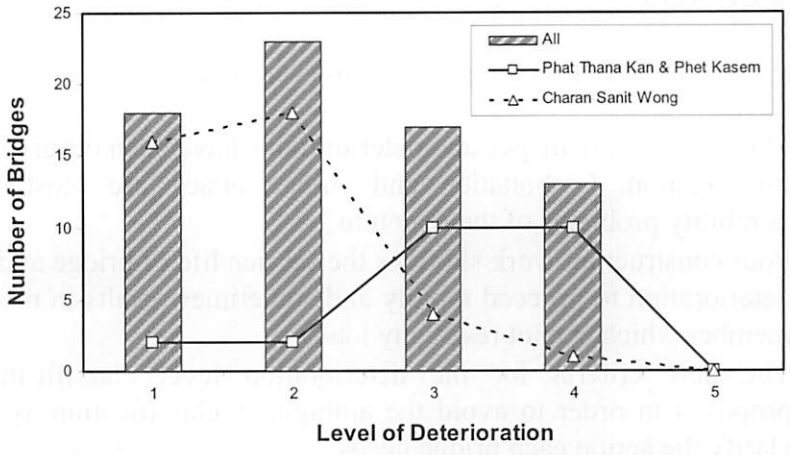

Figure 86: Number of bridges of each level of deterioration

7. DISCUSSION

The investigation data reveals that most of concrete bridges in Bangkok needs careful maintenance program. Note that the sample group locates away from marine environment. It is thus expectable that the concrete bridges in area adjacent to the sea should be much terrible. This fact emphasize the needs for the developing the planning for efficient maintenance, both short-term and long-term.

As a matter of fact, the data collected in this investigation alone is not sufficient to make a planning at all. The other parameters like ages of each bridge, traffic loads, waste water system map, and information of contractor who construct the bridge are also meaningful for planning. The responsible agencies in Thailand (not only BMA but also others) should pay attention in the data collection and systematic analysis which can be done collaboratively across organization boundary. It would be of great value to have a joint central database where all governmental agencies that are responsible for the infrastructure can share and obtain necessary information. The planning in both macroscopic (allocation of budget to each bridge) as well as the microscopic (R&M planning of a single bridge) should be referred in the decision making and budget allocation.

According to the investigation data, numerous types of damages can be observed in different elements of the short-span concrete bridges. Extensively found in this research is the defects caused by the bad design and poor construction control which allow the deterioration of bridges of all type to proceed at faster rate. Therefore, in addition to the well-planned maintenance program, the quality of newly-constructed structure should be strictly checked. In order to be sustainable, not only solving current problems but also preventing upcoming troubles is of crucial significance.

8. CONCLUSION

From the investigation, following conclusion can be done.

- Many types of damages and deteriorations have been observed in the investigation. Carbonation and sulfate attack are mostly found durability problems of the structure.
- Poor construction work shortens the service life of bridge and allows deterioration to proceed rapidly and sometimes results in misshaped member which cannot resist any load.
- The new criteria for the deterioration level classification are proposed in order to avoid the ambiguous classification as well as clarify the action each bridge needs.
- Around 70% of bridges need a deeper inspection and around 40% need the urgent action. The situation is expectable to be more serious in the seashore area.
- The levels of deterioration of bridges in different roads are quite different although they are in the same area. This may be because of the traffic load, construction quality, or average age. This point should be clarified in the further study.

ACKNOWLEDGEMENT

The authors would like to give a great appreciation to a group of students of Sirindhorn International Institute of Technology, Thammasat University, for their strong support in this investigation program. The inspection of this large number of bridges would not be possible without their effort.

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[3] Chongpitaksin, N., "Deterioration Rate & Corrosion of Reinforcement in RC Bridges in Bangkok, Master Thesis, Chulalongkorn University, 1995, (ISBN: 974-632-806-9)

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[5] ACI Committee 201, "Guide for Making a Condition Survey of Concrete in Service", ACI201.1R-92 (Reapproved 1997)

[6] ACI, "Bridge Inspector's Training Manual 90"

APPENDIX A: FULL LIST OF BRIDGES IN THIS INVESTIGATION PROGRAM

ID No.	*Bridge Name*	*Road*
1	Bridge across Mon Canal #1	Charan Sanitwong Road
2	Bridge across Mon Canal #2	Charan Sanitwong Road
3	Bridge across Bang Khun Non Canal #1	Charan Sanitwong Road
4	Bridge across Bang Khun Non Canal #2	Charan Sanitwong Road
5	Bridge across Bang Plu Canal #1	Charan Sanitwong Road
6	Bridge across Bang Plu Canal #2	Charan Sanitwong Road
7	Bridge across Bang Plad Canal #1	Charan Sanitwong Road
8	Bridge across Bang Plad Canal #2	Charan Sanitwong Road
9	Bridge across Bang Pra Kroo Canal #1	Charan Sanitwong Road
10	Bridge across Bang Pra Kroo Canal #2	Charan Sanitwong Road
11	Bridge across Bang Rak Canal #1	Charan Sanitwong Road
12	Bridge across Bang Rak Canal #2	Charan Sanitwong Road
13	Bridge across Sao It Canal #1	Charan Sanitwong Road
14	Bridge across Sao It Canal #2	Charan Sanitwong Road
15	Bridge across Mon Canal #3	Charan Sanitwong Road
16	Bridge across Mon Canal #4	Charan Sanitwong Road
17	Bridge across Sapan Yao Canal #1	Charan Sanitwong Road
18	Bridge across Sapan Yao Canal#2	Charan Sanitwong Road
19	Bridge across Bang Or Canal #1	Charan Sanitwong Road
20	Bridge across Bang Or Canal #2	Charan Sanitwong Road
21	Bridge across Teai Canal #1	Charan Sanitwong Road
22	Bridge across Teai Canal #2	Charan Sanitwong Road
23	Bridge across Mahasorn Canal #1	Petcha Kasem Road
24	Bridge across Mahasorn Canal #2	Petcha Kasem Road
25	Bridge across Thawi Wattana Canal #1	Petcha Kasem Road
26	Bridge across Thawi Wattana Canal #2	Petcha Kasem Road
27	Bridge across Yai Teab Canal #1	Petcha Kasem Road
28	Bridge across Yai Teab Canal #2	Petcha Kasem Road
29	Bridge across Bang Wa Canal #1	Petcha Kasem Road
30	Bridge across Bang Wa Canal #2	Petcha Kasem Road
31	Bridge across Rong Yao Canal #1	Petcha Kasem Road
32	Bridge across Rong Yao Canal #2	Petcha Kasem Road
33	Bridge across Lat Ta Glan Canal	Soi Charan Sanitwong 13
34	Bridge across Lat Wat Chim Canal	Soi Charan Sanitwong 13
35	Bridge across Sarn Jao Canal	Soi Charan Sanitwong 13
36	Bridge across Tanode Canal	Soi Charan Sanitwong 13
37	Bridge across Bangkok Yai Canal	Soi Charan Sanitwong 13
38	Bridge across Lad Mayom Canal	Soi Charan Sanitwong 35
39	Bridge across Lam Padong Canal	Soi Charan Sanitwong 35
40	Bridge (No name) #1	Soi Charan Sanitwong 35
41	Bridge (No name) #2	Soi Charan Sanitwong 35
42	Bridge across Bang Phrom Canal	Soi Charan Sanitwong 35
43	Bridge (No name) #3	Soi Charan Sanitwong 35
44	Bridge across Lad Wat Mai Canal	Soi Charan Sanitwong 35
45	Bridge across Lad Wat Sapan Canal	Soi Charan Sanitwong 35
46	Bridge across Lad Phleng Canal	Soi Charan Sanitwong 35
47	Bridge (No name) #4	Soi Charan Sanitwong 35
48	Bridge across Lat Thom Ya Canal	Soi Charan Sanitwong 35
49	Bridge across Wat Kaew Canal	Soi Charan Sanitwong 35
50	Bridge across Bang Phrom Canal	Soi Charan Sanitwong 35
51	Bridge across Shak Pra Canal	Bang Khun Non Road

52	Bridge across Wat Chao Arm Canal	Bang Khun Non Road
53	Bridge across Bang Khun Non Canal #3	Bang Khun Non Road
54	Bridge across Ratcha Montri Canal	Phattha Nakan Road
55	Bridge across Bang Ranae Canal	Phattha Nakan Road
56	Bridge across Ta Paem Canal	Phattha Nakan Road
57	Bridge across Ta Cham Canal	Phattha Nakan Road
58	Bridge (No name) #5	Phattha Nakan Road
59	Bridge across Bang Wa Canal	Phattha Nakan Road
60	Bridge across Wat Ang Kaew Canal	Phattha Nakan Road
61	Bridge across Bang Chak Canal #1	Soi Petcha Kasem 88
62	Bridge across Lung Tui Canal	Racha Montri Road
63	Bridge across Satharana Prayot Canal	Racha Montri Road
64	Bridge across Racha Montri Canal	Racha Montri Road
65	Bridge (No name) #7	Soi Petcha Kasem 58
66	Bridge across Bang Duan Canal #1	Soi Petcha Kasem 58
67	Bridge across Bang Duan Canal #2	Soi Petcha Kasem 58
68	Bridge across Lam Madong Canal	Soi Petcha Kasem 58
69	Bridge across Bang Chak Canal#2	Soi Petcha Kasem 48
70	Bridge across Maha Sorn Canal	Liab Klong Phasi Charoen Road
71	Bridge (No name) #8	Liab Klong Phasi Charoen Road
72	Bridge across Bang Khae Canal	Soi Petcha Kasem 63

APPENDIX B: DETAILED INSPECTION RESULTS OF BRIDGES IN THIS INVESTIGATION PROGRAM

1. Mon Canal – Charan Sanitwong Road (Heading to Thar Phra Intersection)

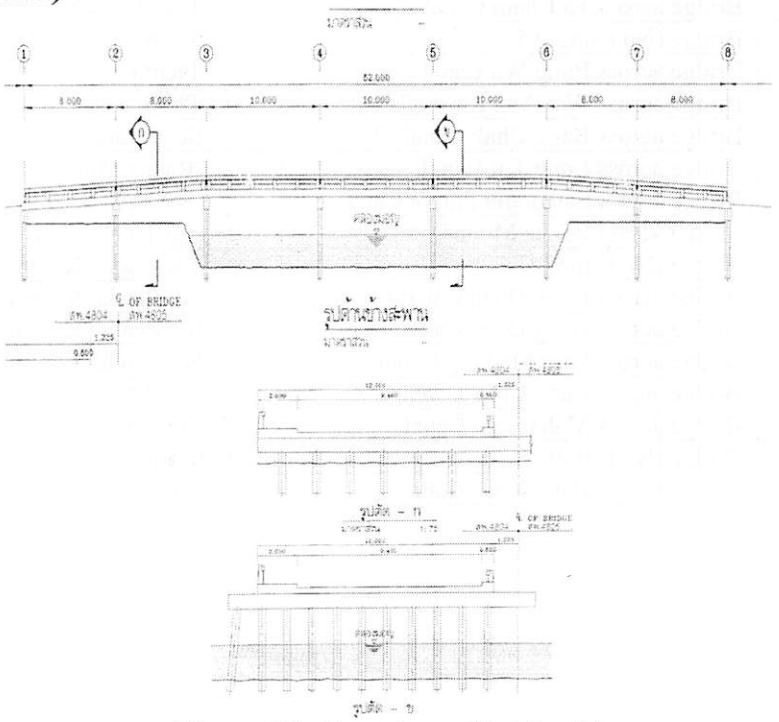


Figure B1: Drawing of Bridge #1

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Place RC
Slab	:	Cast-in-Place RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Erosion
Beam	:	Spalling, Corrosion, Change of Surface Color
Slab	:	Spalling, Corrosion

Deterioration Level: 3

Figure B2: Spalling and corrosion of column

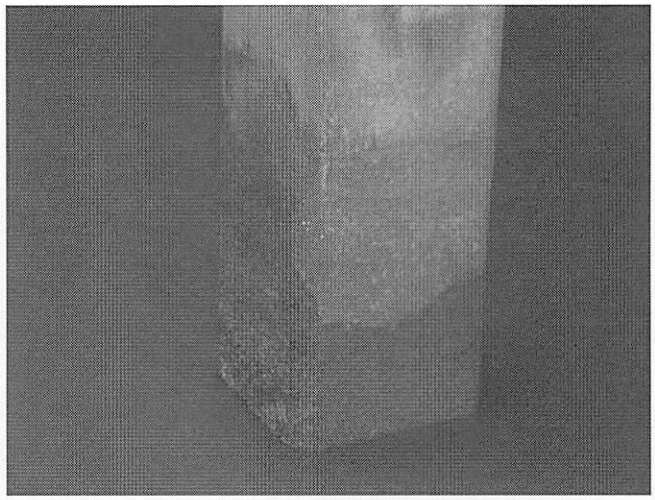


Figure B3: Portion of column damaged by sulfate attack and erosion

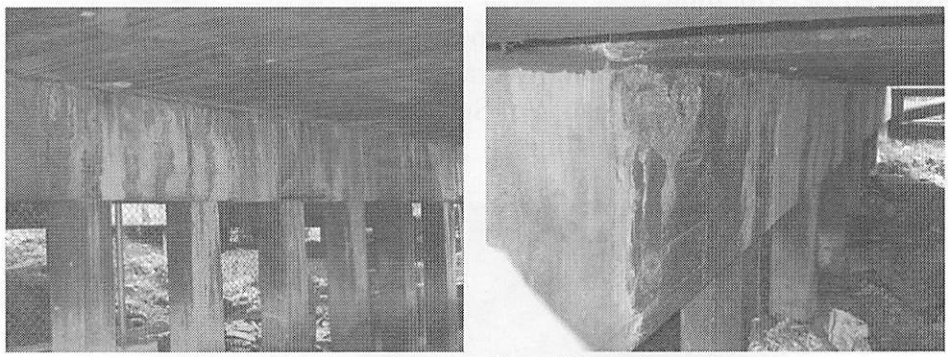


Figure B4: Leaching and spalling of cap beam

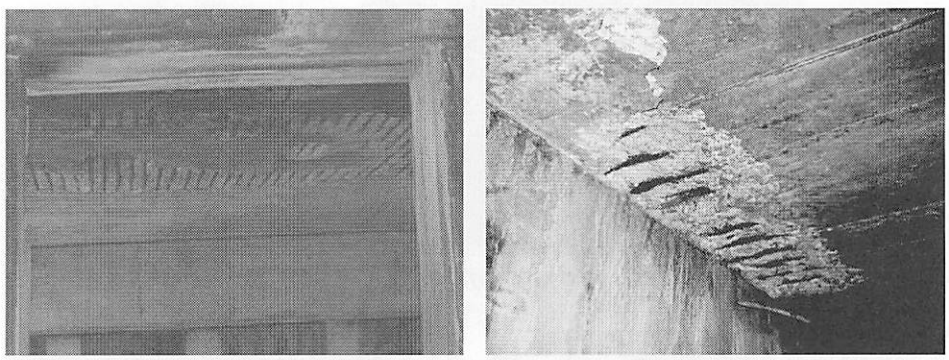
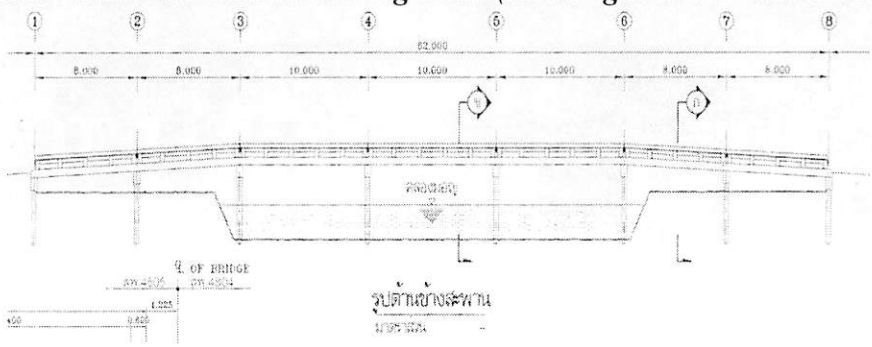


Figure B5: Concrete spalling and corrosion of re-bar found in Slab

2. Mon Canal – Charan Sanitwong Road (Heading to Fai Chai Junction)



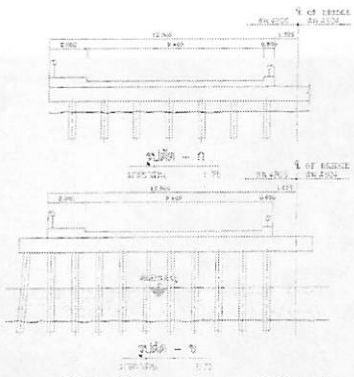


Figure B6: Drawing of Bridge #2

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Place RC
Slab	:	Cast-in-Place RC

Observed Deterioration:

Pier	:	Spalling, Corrosion
Beam	:	Spalling, Cracking, Corrosion, Change of Surface Color
Slab	:	Spalling

Deterioration Level: 3

Figure B7: Damage in column

Figure B8: Change of surface color

Figure B9: Spalling of the cast-in-place slab

3. Bang Khun Non Canal – Charan Sanitwong Road (Heading to Fai Chai Junction)

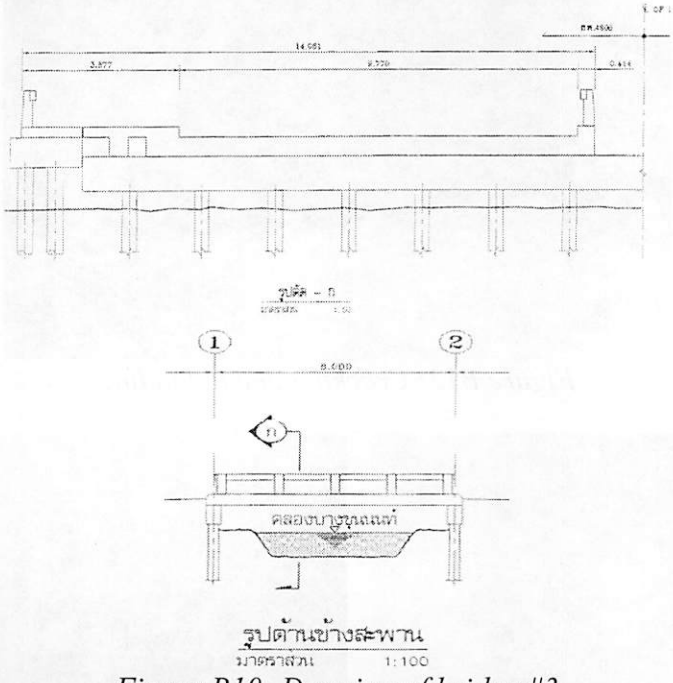


Figure B10: Drawing of bridge #3

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Honeycombs, Corrosion (Wall)
Beam	:	Honeycombs, Change of Surface Color
Slab	:	Spalling, Corrosion, Honeycombs

Deterioration Level: 2

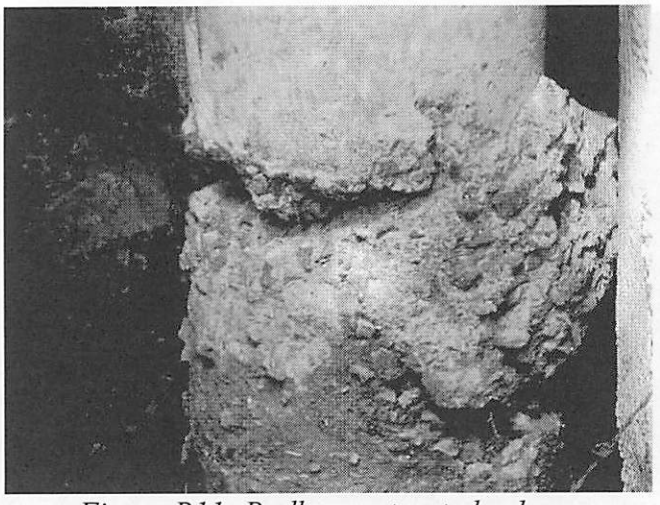


Figure B11: Badly-constructed column

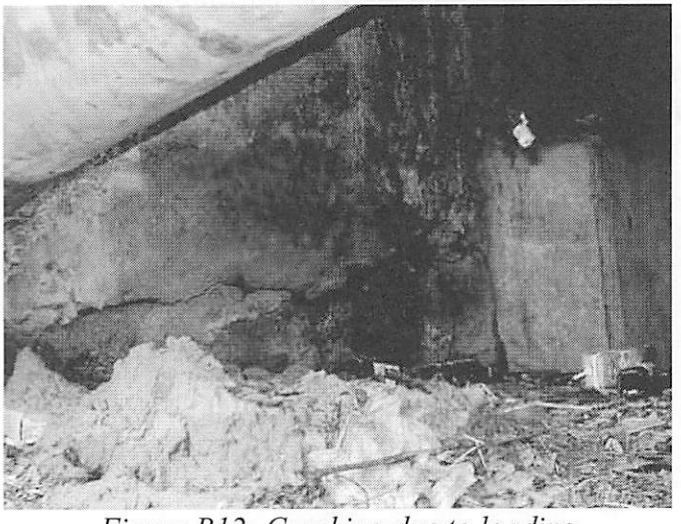


Figure B12: Cracking due to loading

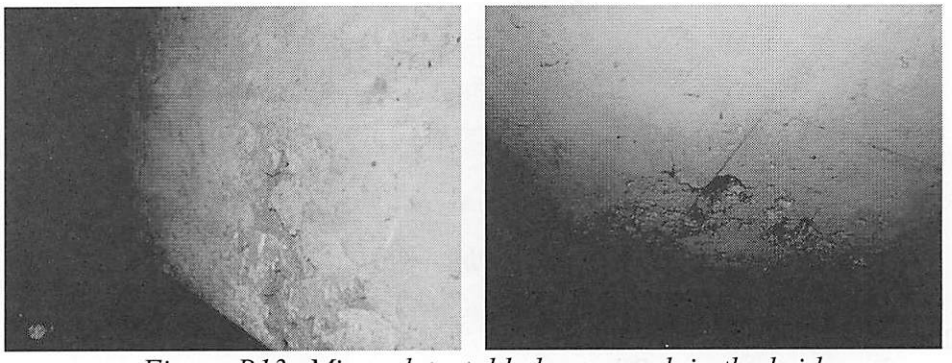


Figure B13: Minor detectable honeycomb in the bridge

4. Bang Khun Non Canal – Charan Sanitwong Road (Heading to Rama VII Bridge)

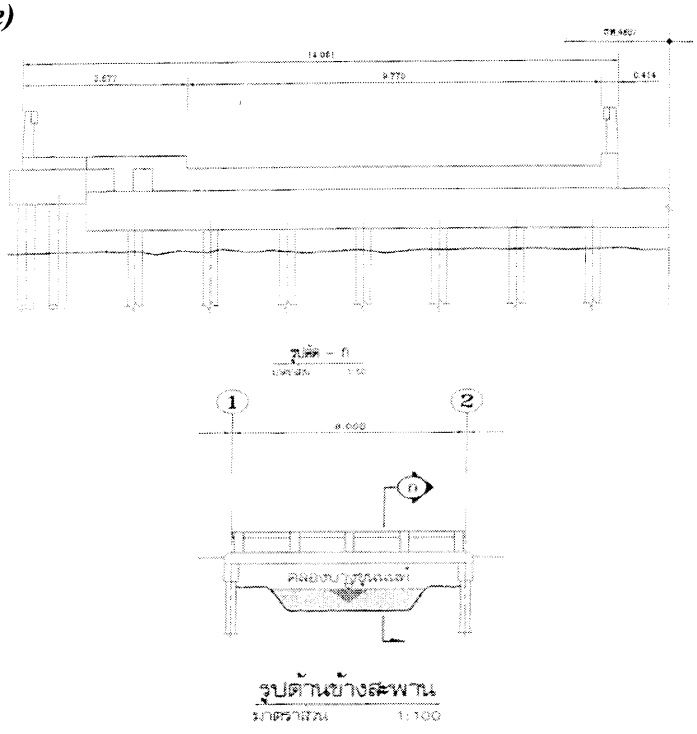


Figure B14: Drawing of Bridge #4

Type of Structure:

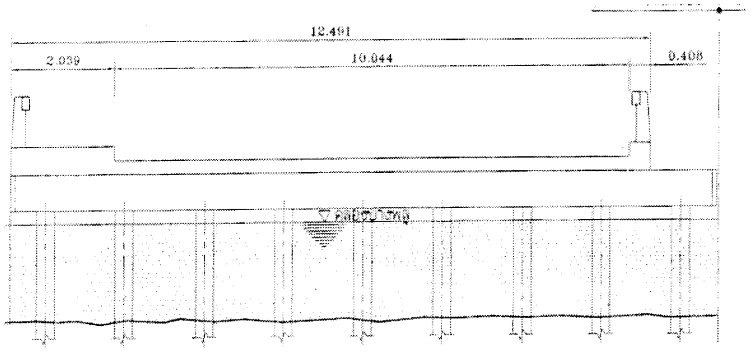
Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Beam	:	N/A
Slab	:	N/A
Note	:	Cracking and Spalling on Guard Rail

Deterioration Level: N/A

5. Bang Plu Canal – Charan Sanitwong Road (Heading to Bang Phlat Intersection)



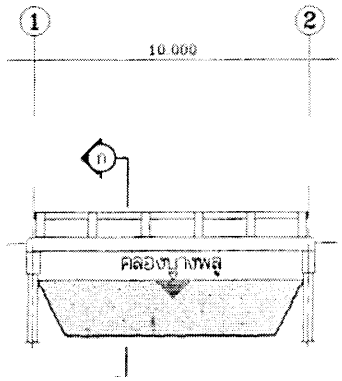


Figure B15: Drawing of Bridge #5

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	No Damage
Beam	:	Poor Construction (Holes), Water Leakage
Slab	:	Spalling

Deterioration Level: 1

6. Bang Plu Canal – Charan Sanitwong Road (Heading to Rama VII Bridge)

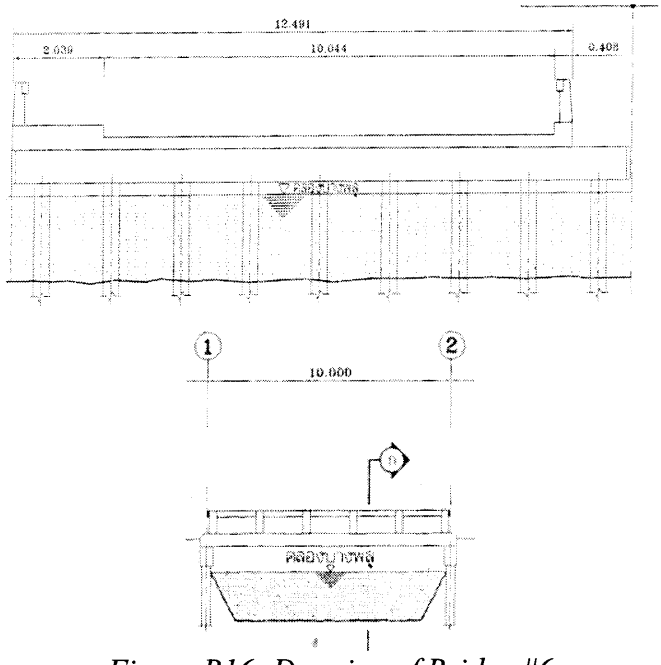


Figure B16: Drawing of Bridge #6

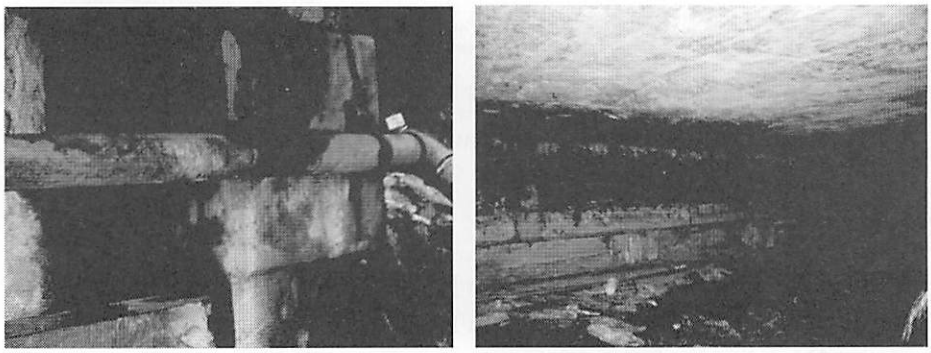
Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier : Cracks, Erosion
Beam : Honeycomb, Change of Surface Color
Slab : No Damage

Deterioration Level: 1



FigureB17: Leakage of water

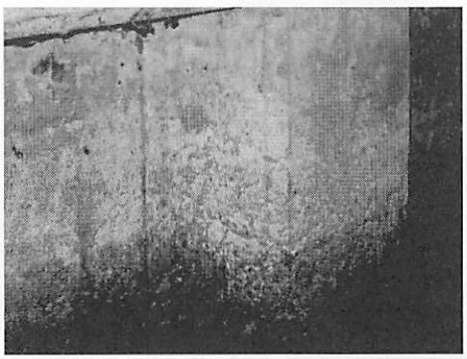


Figure B18: Erosion observable in tidal zone

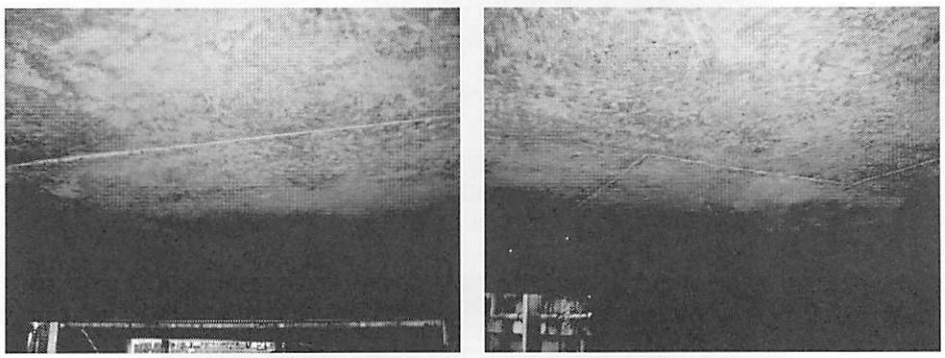
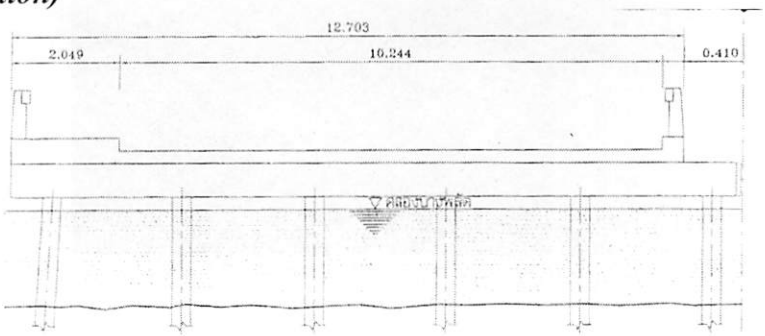


Figure B19: No damage in slab

7. Bang Plad Canal – Charan Sanitwong Road (Heading to Bang Phlat Intersection)



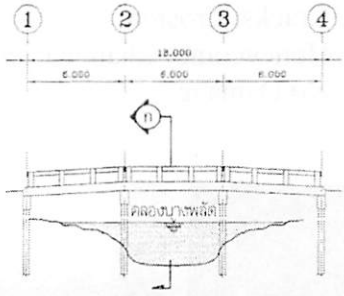


Figure B20: Drawing of bridge #7

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Peir	:	Spalling, Erosion
Beam	:	Spalling
Slab	:	No Damage

Deterioration Level: 2

Figure B21: Damage at the connection of pier and cap beam

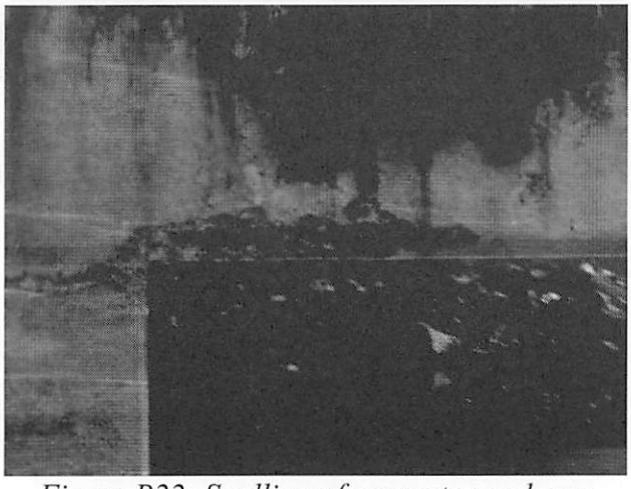


Figure B22: Spalling of concrete cap beam

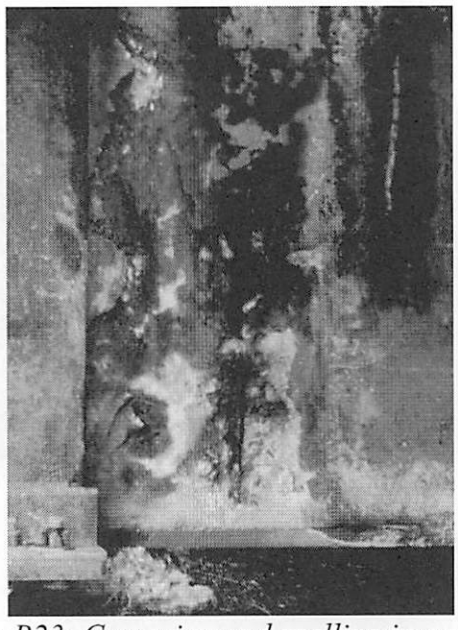


Figure B23: Corrosion and spalling in cap beam

8. Bang Plad Canal – Charan Sanitwong Road (Heading to Rama VII Bridge)

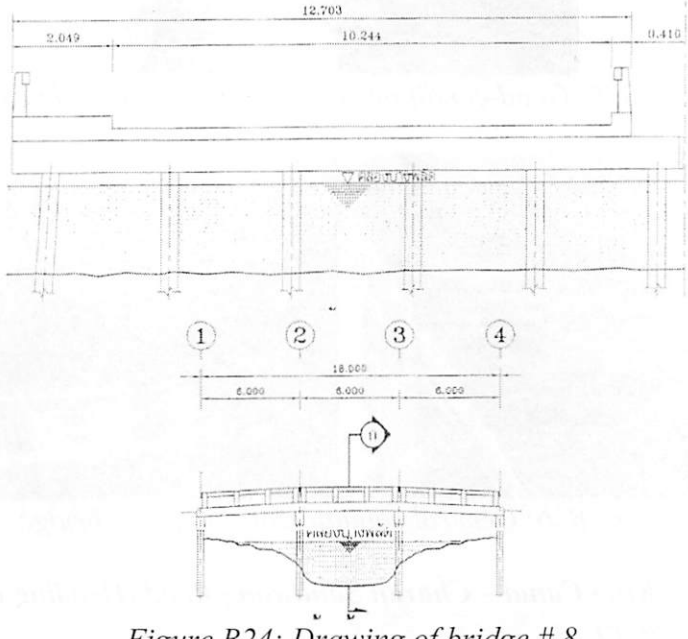


Figure B24: Drawing of bridge # 8

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Peir	:	Honeycombs, Erosion
Beam	:	Spalling, Change of Surface Color
Slab	:	Spalling, Corrosion <= For Cantilever Slab

No Damage <= For Middle Slab

Deterioration Level: 2

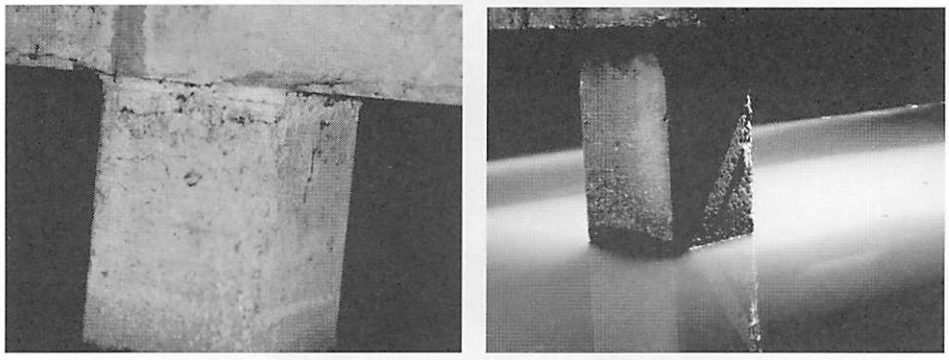


Figure B25: Minor honeycombs at connection with cap beam

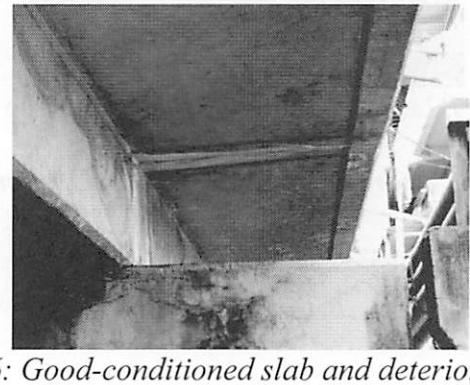


Figure B26: Good-conditioned slab and deteriorated beams

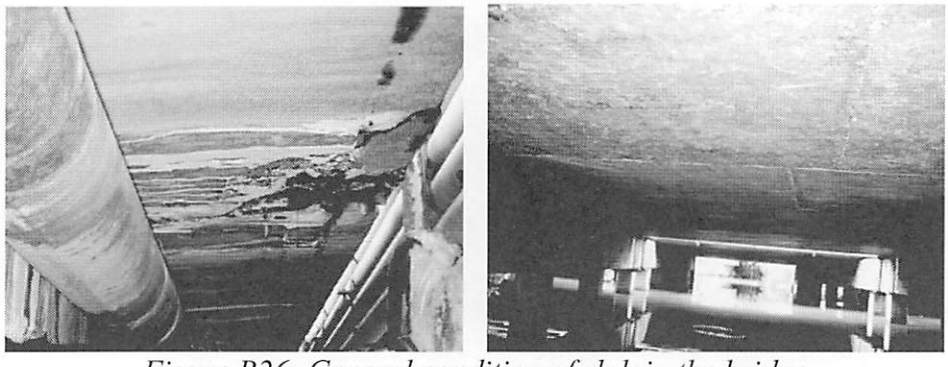
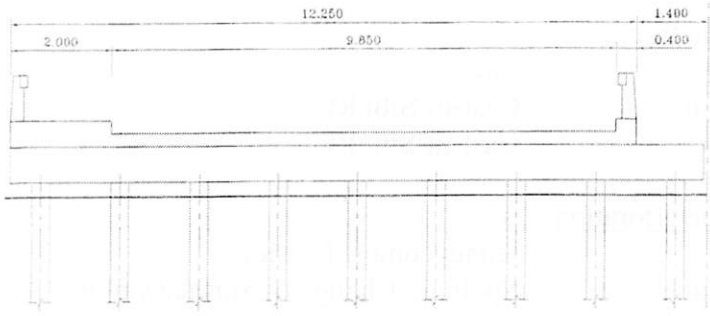


Figure B26: General condition of slab in the bridge

9. Bang Phra Kroo Canal – Charan Sanitwong Road (Heading to Bang Phlat Intersection)



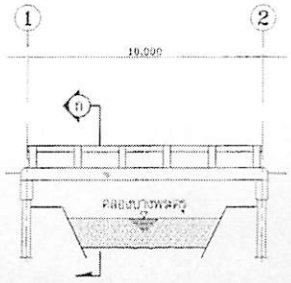


Figure B27: Drawing of bridge # 9

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling (Wall), Corrosion (Wall)
Beam	:	Change of Surface Color, Spalling
Slab	:	Poor Construction

Deterioration Level: 2

Figure B28: Spalling and corrosion in wall

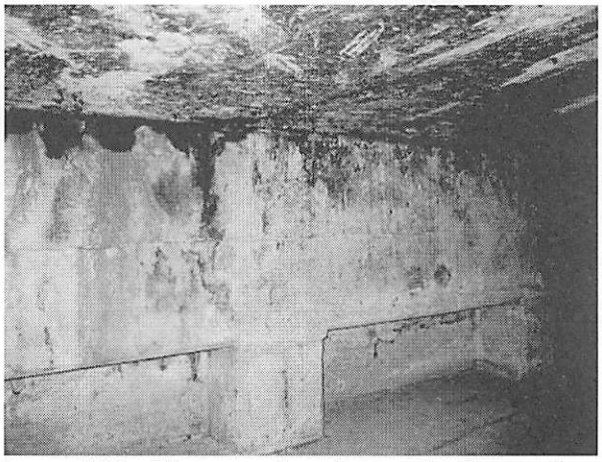


Figure B29: Change of surface color in cap beam

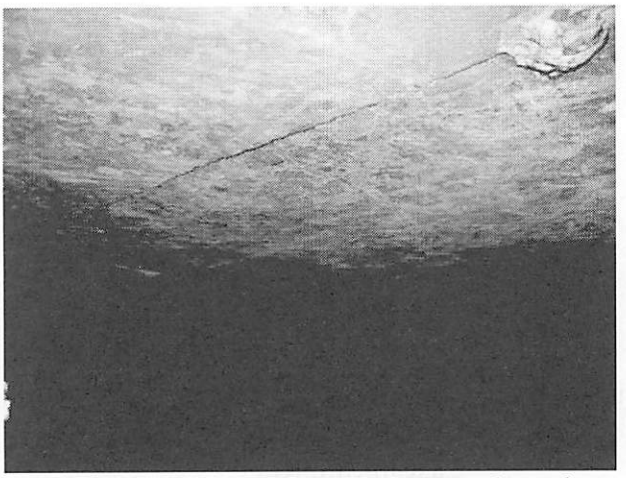


Figure B30: Rough surface indicating low quality of construction

10. Bang Pra Khroo Canal – Charan Sanitwong Road (Heading to Rama VII Bridge)

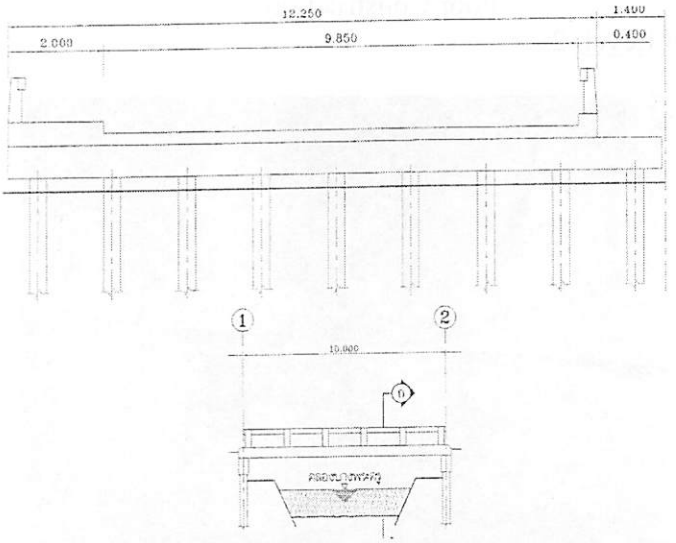


Figure B31: Drawing of bridge#10

Type of Structure:

Pier	:	Pile
Girder	:	-
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Honeycomb at connection with cap beam
Beam	:	Change of Surface Color
Slab	:	Spalling, Corrosion

Deterioration Level: 2

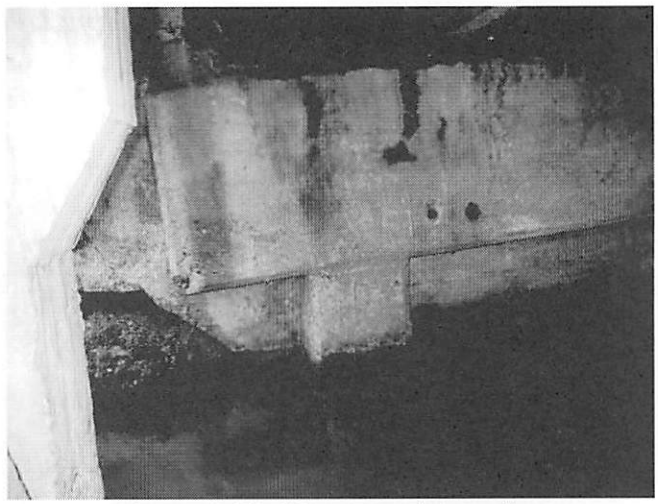


Figure B32: Honeycomb in colum

Figure B33: Change of surface color by water leakage

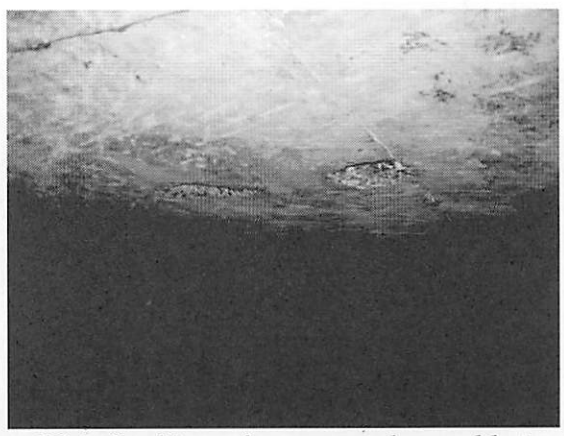


Figure B34: Spalling of concrete observable in slab

11. Bang Rak Canal – Charan Sanitwong Road (Heading to Bang Phlat Intersection)

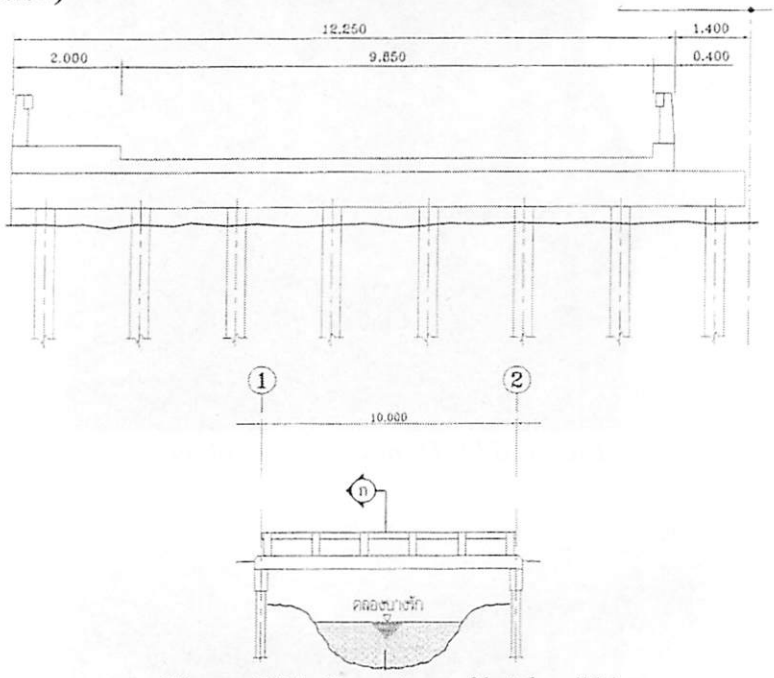


Figure B35: Drawing of bridge #11

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Beam	:	No Damage
Slab	:	Honeycombs

Deterioration Level: 1

Figure B36:Honeycombs at the edge of slab caused by poor construction

12. Bang Rak Canal – Charan Sanitwong Road (Heading to Rama VII Bridge)

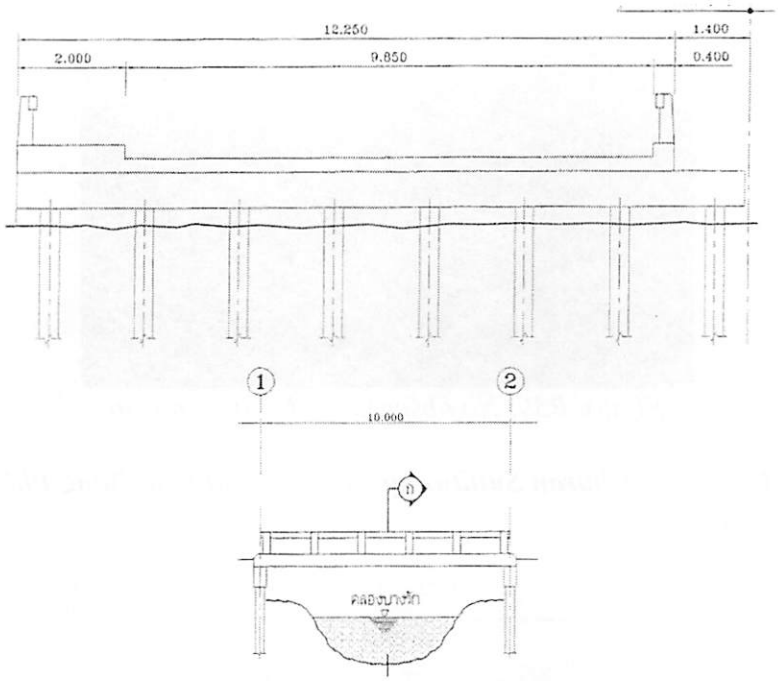


Figure B37: Drawing of bridge #12

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Beam	:	Change of Surfacce Color, Corrosion
Slab	:	No Damage

Deterioration Level: 1

Note: There is a spalling of guard rail caused by carbonation

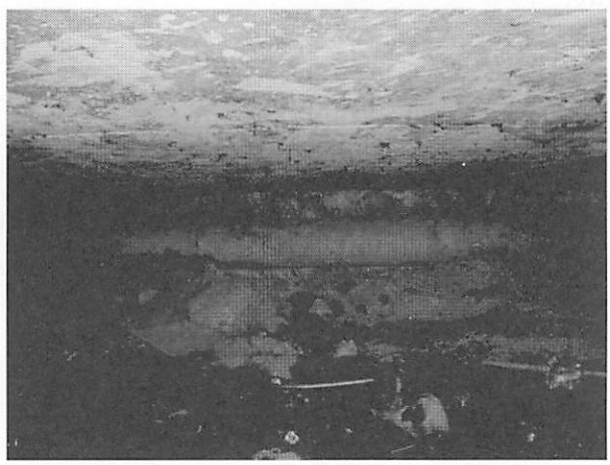


Figure B38: Rust color indicating corrosion inside a wall

Figure B39: No observable damage in slab

13. Sao It Canal – Charan Sanitwong Road (Heading to Bang Phlat Intersection)

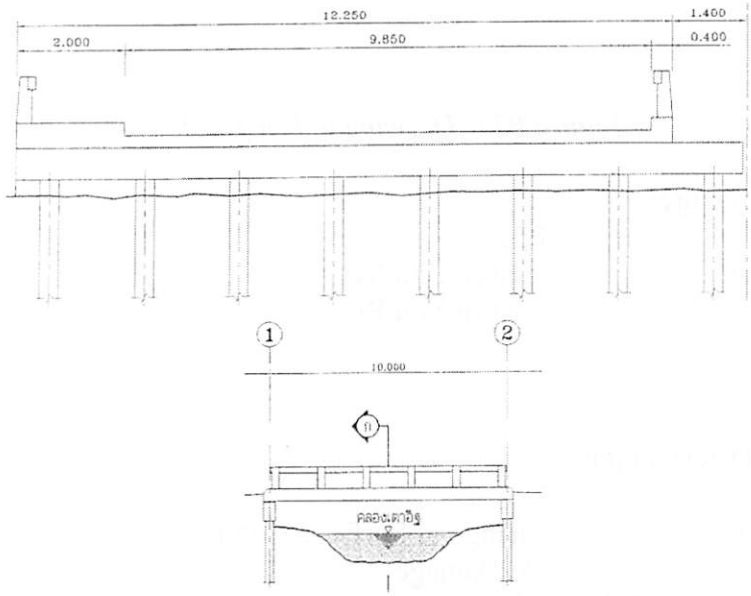


Figure B40: Drawing of bridge #13

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Beam	:	Change of Surface Color, Corrosion
Slab	:	Spalling

Deterioration Level: 2

Note: There is spalling caused by carbonation in a guard rail

Figure B41: Small corroded area observed in beam

Figure B42: Small honeycombs at the head of column

14. Sao It Canal – Charan* Sanitwong Ro*ad (Heading to Rama VII Bridge)

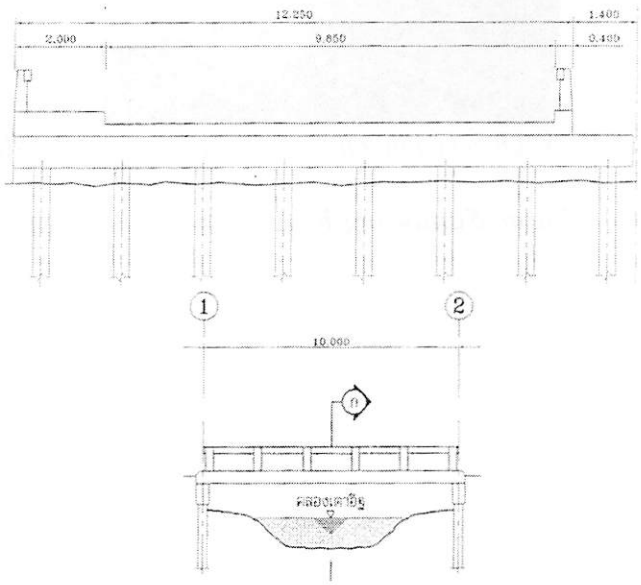


Figure B43: Drawing of bridge #14

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	No Damage
Beam	:	Water Leakage, Change of Surface Color
Slab	:	Change of Surface Color

Deterioration Level: 1

Note: Spalling caused by carbonation is found in guard rails

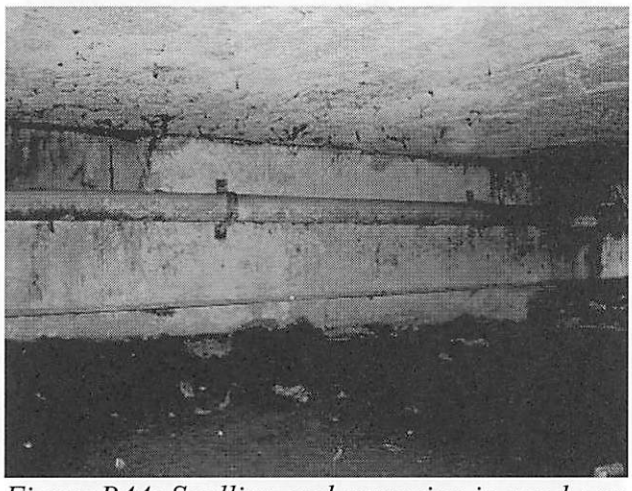


Figure B44: Spalling and corrosion in cap beam

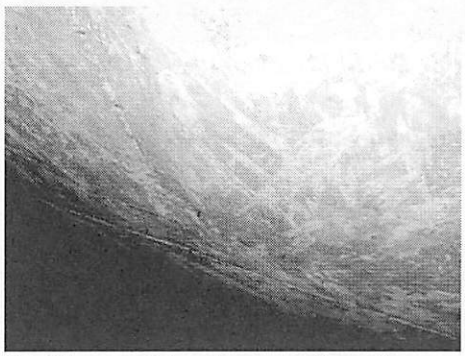
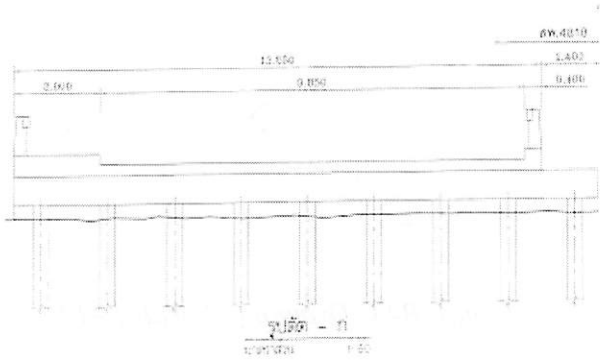


Figure B45: Observable change of surface color in slab

15. Mon Canal – Charan Sanitwong Road (Heading to Bang Phlat Intersection)



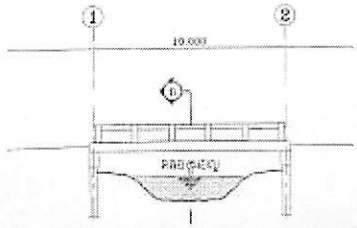


Figure B46: Drawing of bridge #15

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Beam	:	Honeycombs, Change of Surface Color
Slab	:	Poor Construction (Bottom Surface)

Deterioration Level: 1

Figure B47: Observable erosion in column

Figure B48: Rust color and honeycombs found in cap beam

Figure B49: Rough surface of slab caused by poor construction

16. Mon Canal – Charan Sanitwong Road (Heading to Rama VII Bridge)

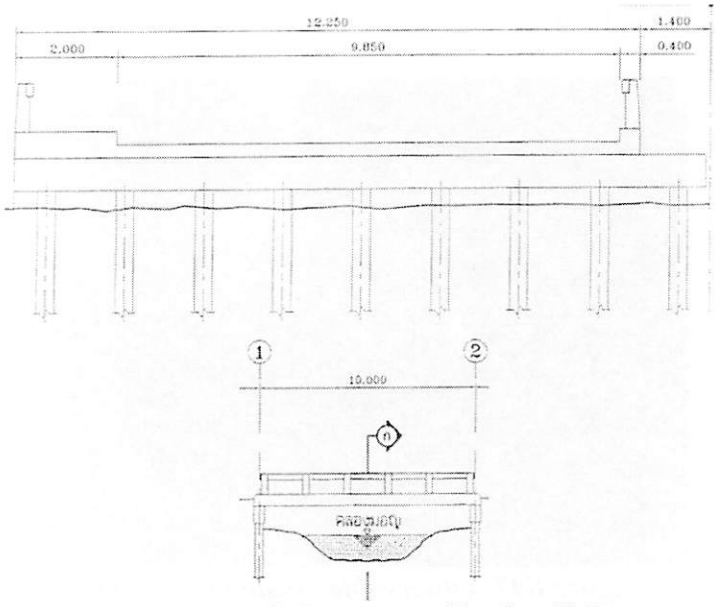


Figure B50: Drawing of bridge #16

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Beam	:	Change of Surface Color
Slab	:	No Damage

Deterioration Level: 1

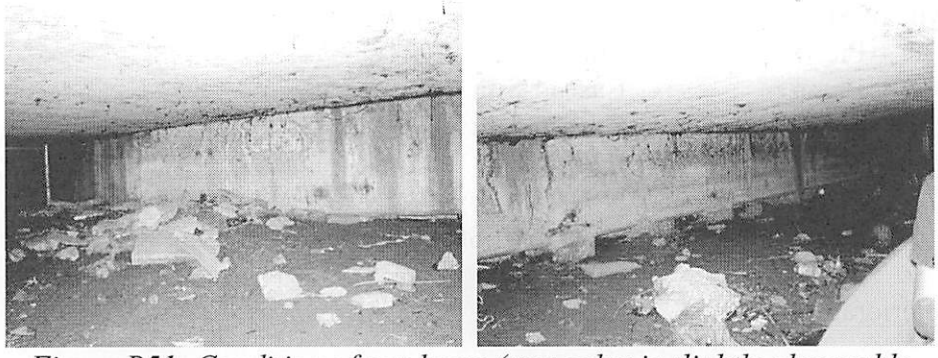


Figure B51: Condition of cap beam (rust color is slightly observable

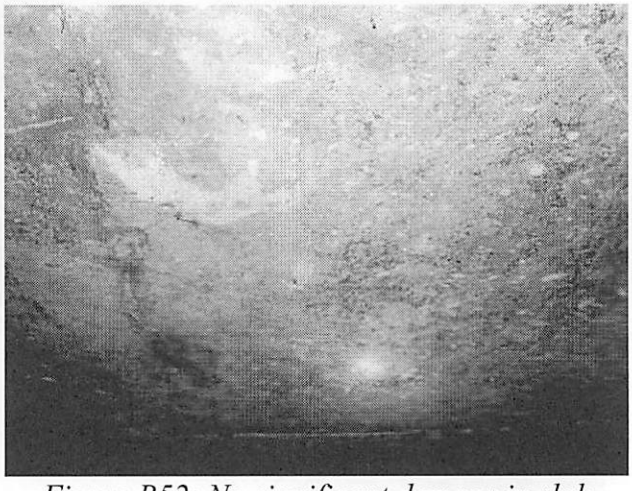


Figure B52: No significant damage in slab

17. Sapan Yao Canal – Charan Sanitwong Road (Heading to Bang Phlat Intersection)

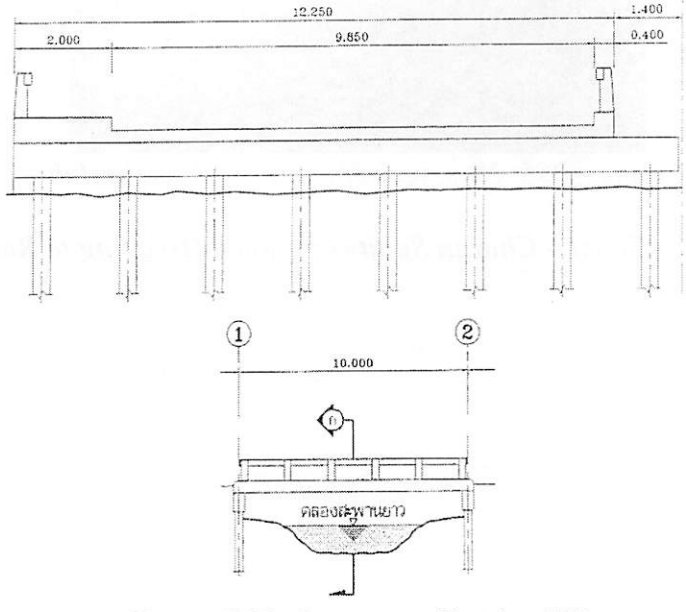


Figure B53: Drawing of bridge #17

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Beam	:	Change of Surface Color, Emerging Re-Bar
Slab	:	No Damage

Deterioration Level: 1

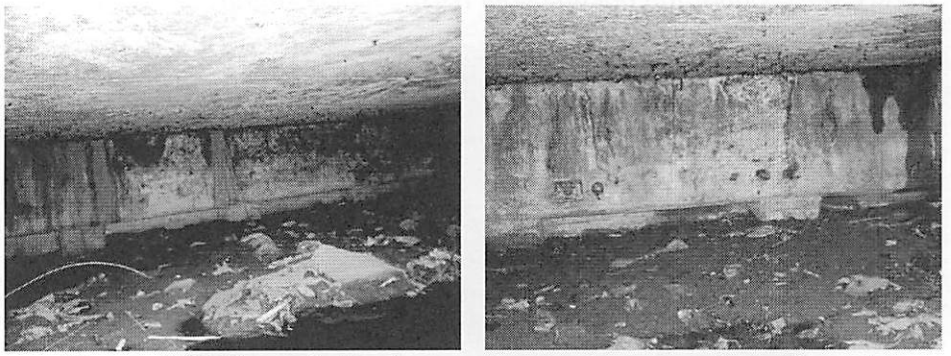
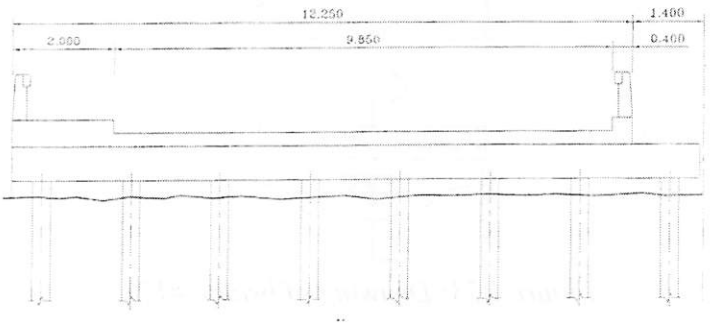


Figure B54:Corroded re-bar and rust color on surface of cap beam

Figure B55: No severe damage observed in slab

18. Sapan Yao Canal – Charan Sanitwong Road (Heading to Rama VII Bridge)



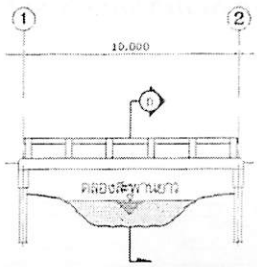


Figure B56: Drawing of bridge #18

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Beam	:	Change of Surface Color
Slab	:	Spalling

Deterioration Level: 2

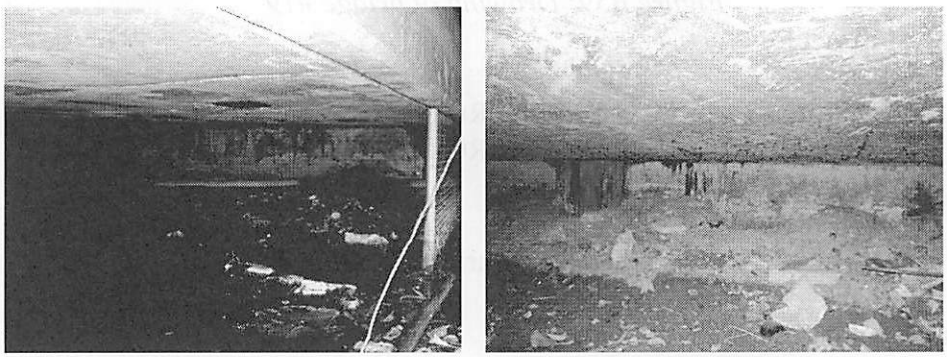


Figure B57: Rust color and trace of water leakage observable in cap beam

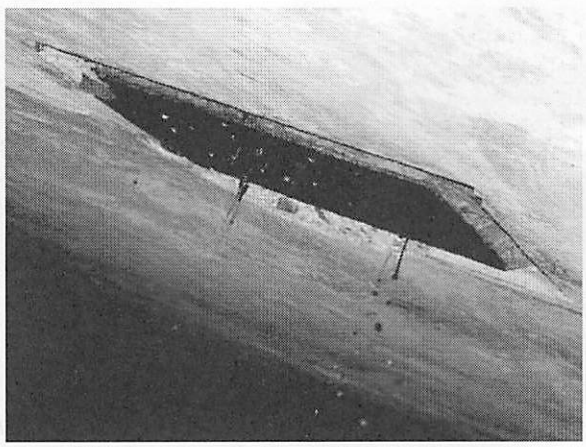


Figure B58: Spalling taking place around water duct

19. Bang-Or Canal – Charan Sanitwong Road (Heading to Bang Phlat Intersection)

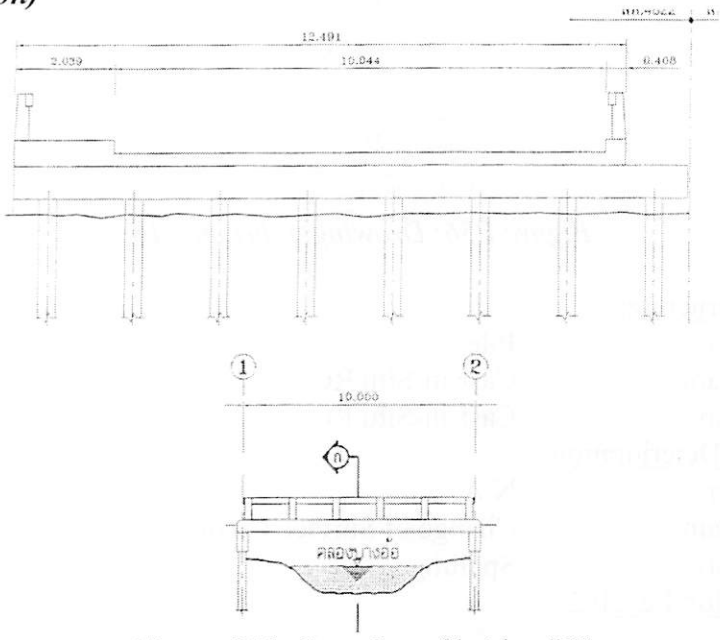


Figure B59: Drawing of bridge #19

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Beam	:	Change of Surface Color
Slab	:	Spalling

Deterioration Level: 2

Figure B60: Change of surface color of cap beam

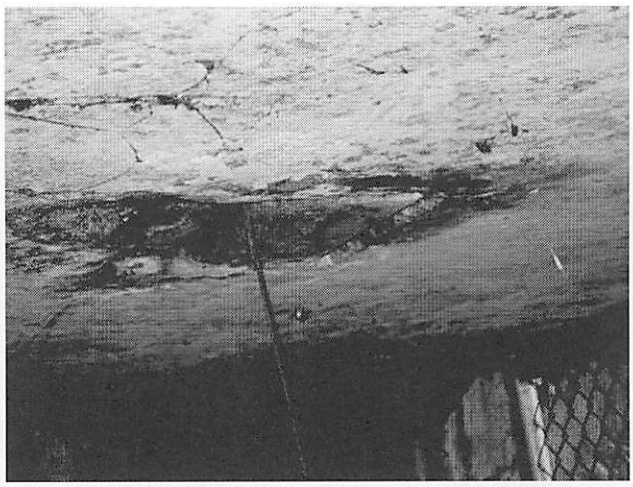


Figure B61: Spalling occurred around the duct

20. Bang-OR Canal – Charan Sanitwong Road (Heading to Rama VII Bridge)

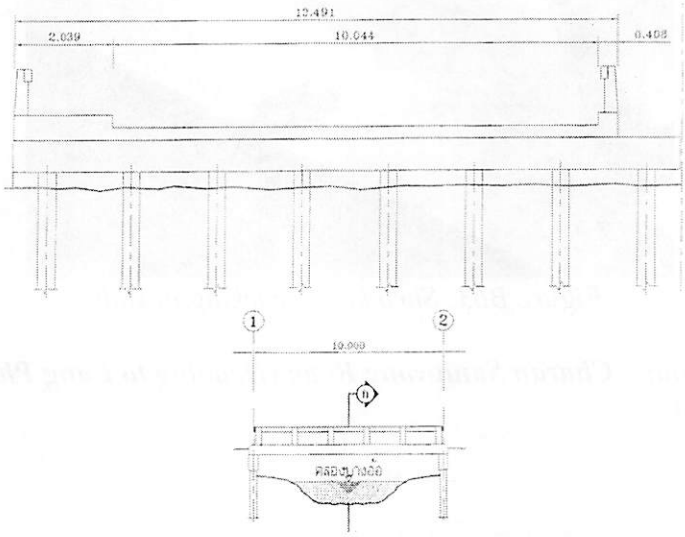


Figure B62: Drawing of bridge #20

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Beam	:	Change of Surface Color
Slab	:	Small Shrinkage Crack (w<0.3mm)

Deterioration Level: 2

Figure B62: Cap Beam: General condition of cap beam (Rust color)

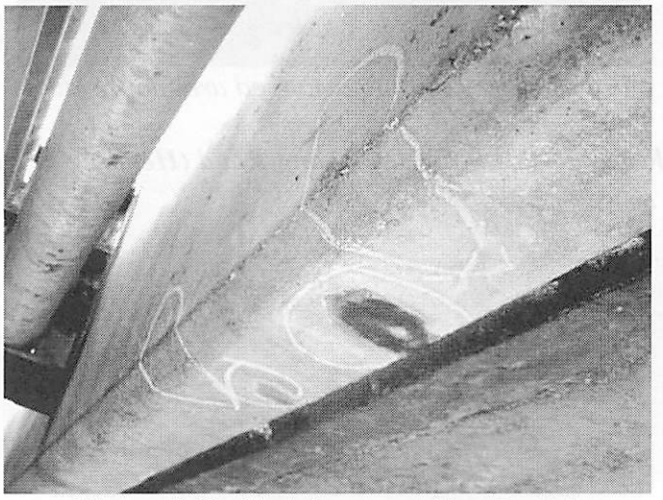


Figure B63: Shrinkage cracking in slab

21. Toei Canal – Charan Sanitwong Road (Heading to Bang Phlat Intersection)

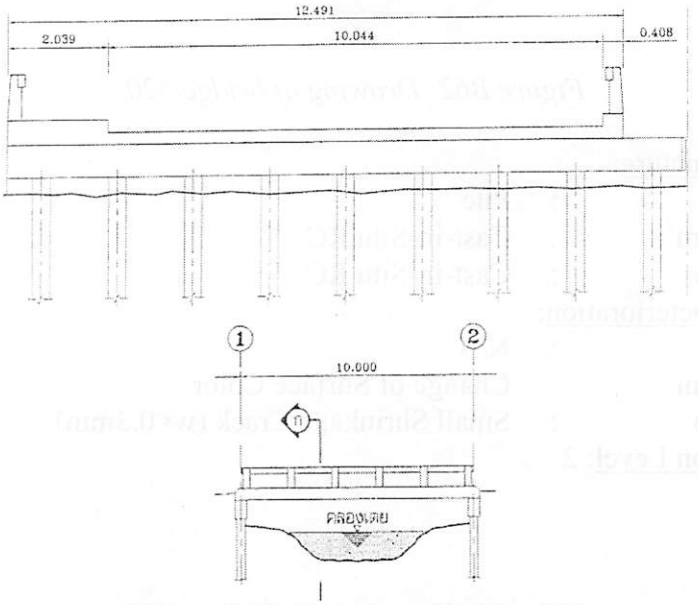


Figure B64: Drawing of bridge #21

Type of Structure:

Pier : Pile

Beam : Cast-in-Situ RC
Slab : Cast-in-Situ RC

Observed Deterioration:

Pier : N/A
Beam : Cracking, Change of Surface Color
Slab : Spalling caused by carbonation

Deterioration Level: 2

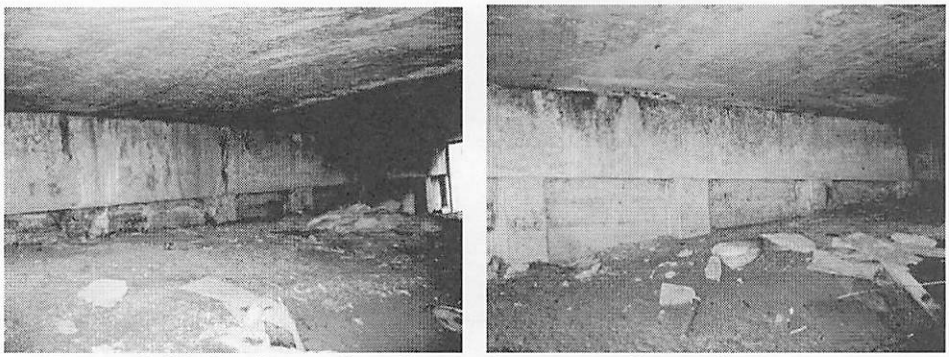


Figure B65: Surface color changed to grey color with some rust in cap beam

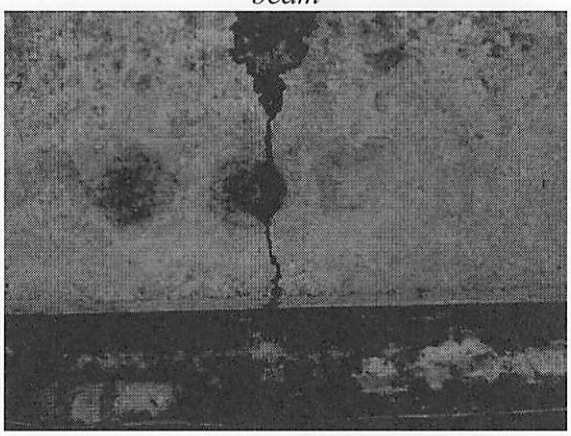


Figure B66: Cracking found on cap beam's surface

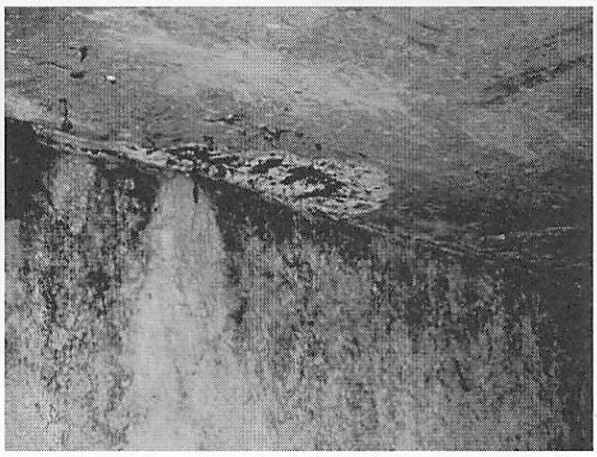


Figure B67: Corrosion of re-bar found at the connection between slab and wall

22. Toei Canal – Charan Sanitwong Road (Heading to Rama VII Bridge)

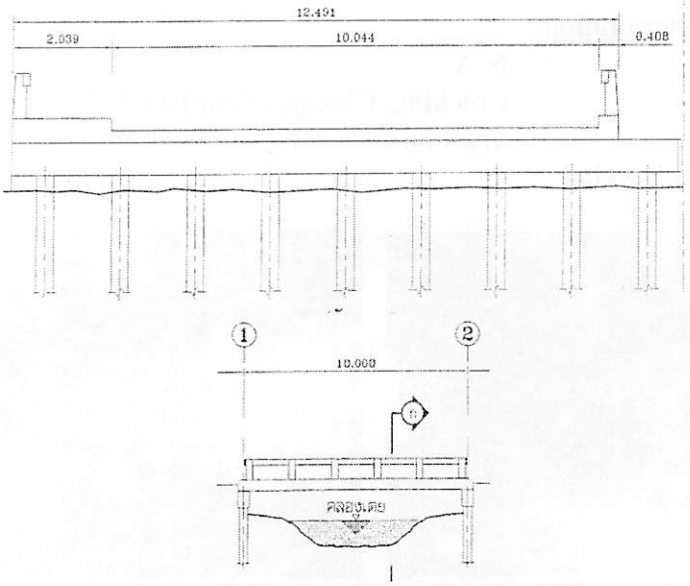


Figure B68: Drawing of bridge #22

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Beam	:	Change of Surface Color
Slab	:	Change of Surface Color

Deterioration Level: 1

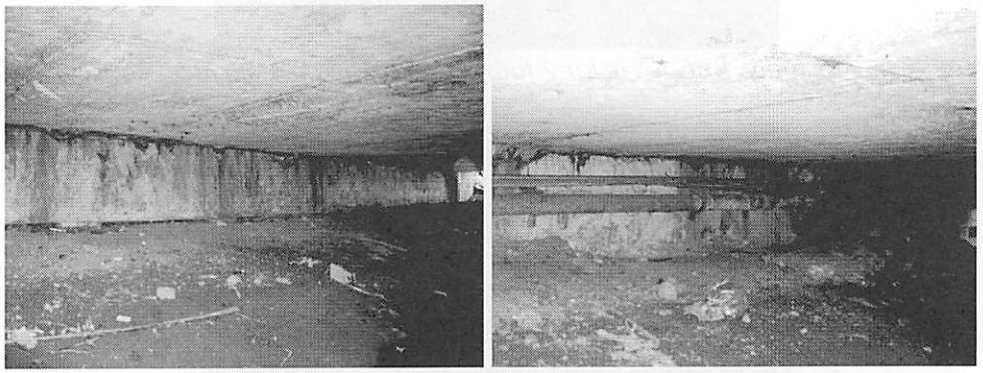


Figure B69 : Surface color change in cap beam

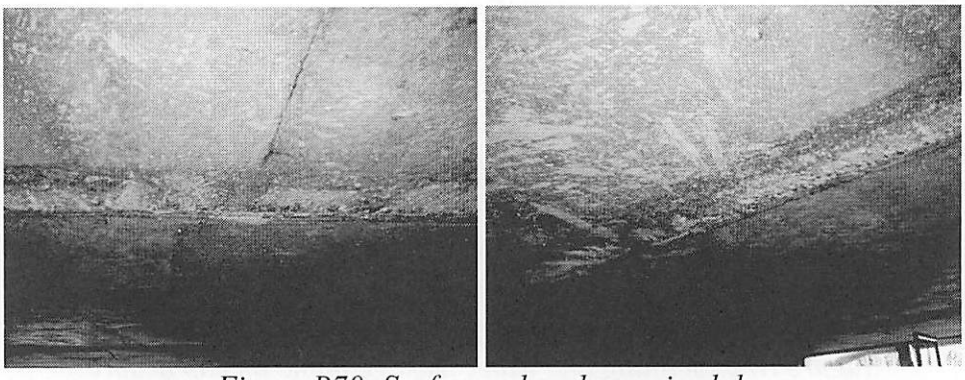


Figure B70: Surface color change in slab

23. Maha Sorn Canal – Petcha Kasem Road (Heading to Petch Kasem 79)

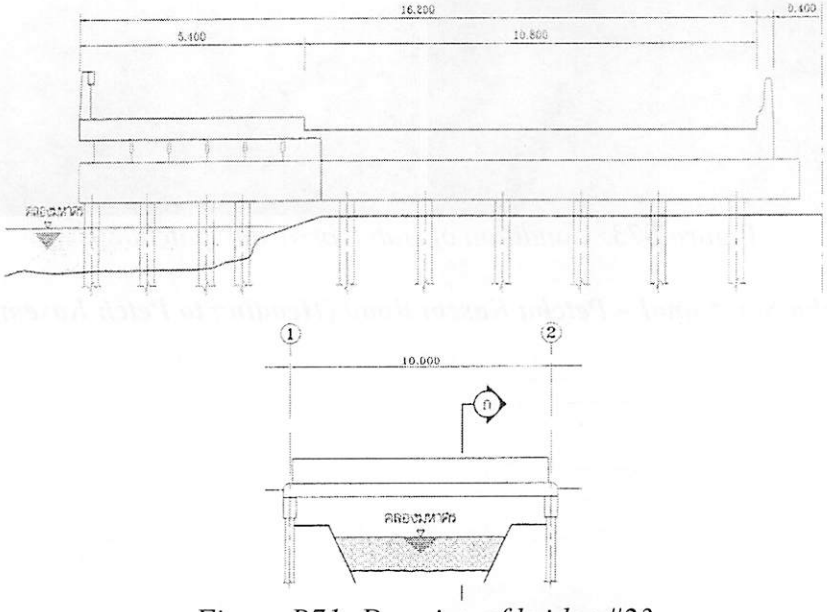


Figure B71: Drawing of bridge #23

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Beam	:	Spalling, Crack caused by concentrated load, Emerging Steel
Slab	:	Spalling, Change of Surface Color, Honeycombs, Water Leakage, Crack caused by lateral movement

Deterioration Level: 2

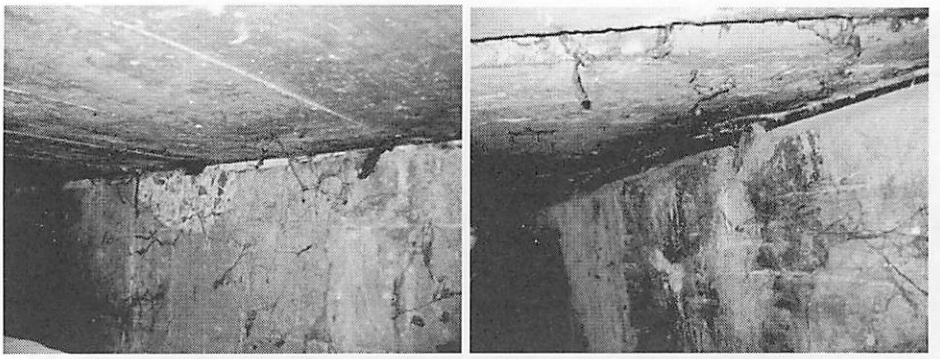


Figure B72: Spalling and water leakage found on cap beams

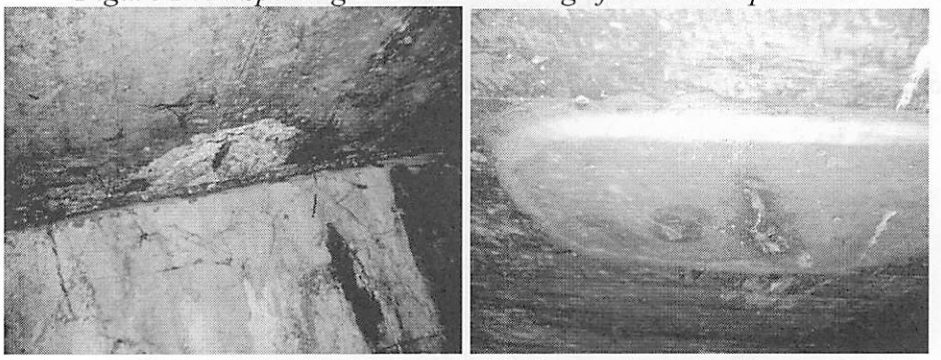


Figure B73: Condition of slab (corrosion, patching)

24. Maha Son Canal – Petcha Kasem Road (Heading to Petch Kasem 81)

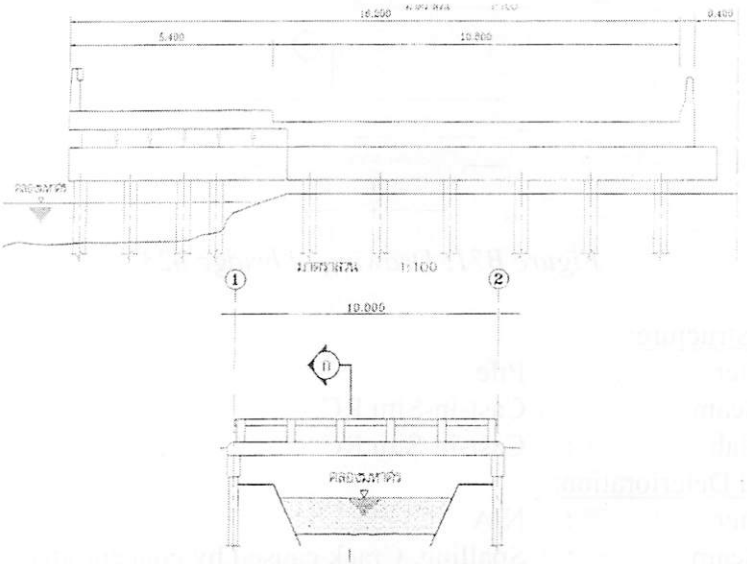


Figure B74: Drawing of bridge #24

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling
Beam	:	No Damage
Slab	:	Honeycombs, Water Leakage

Deterioration Level: 1

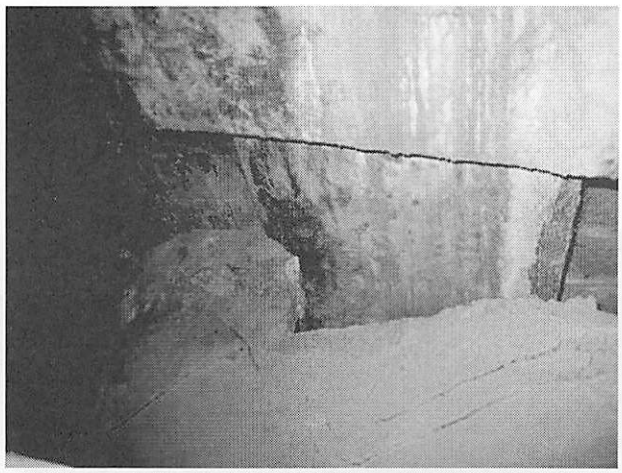


Figure B75: Small spalling observed on pier

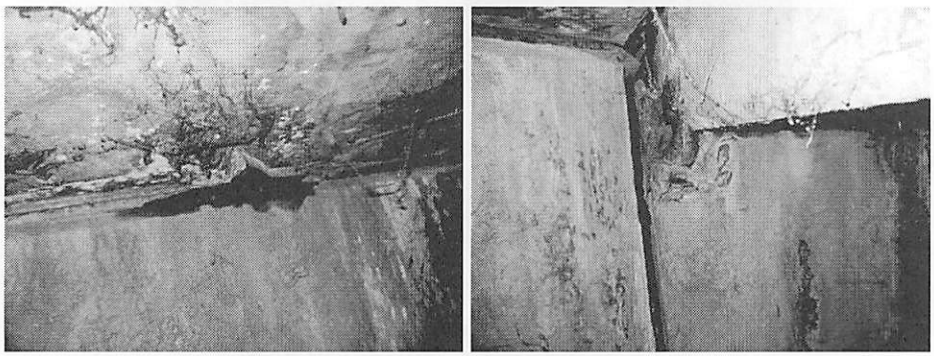


Figure B76: Spalling and corrosion in slab caused by leakage of water

25. Khlong Thawi Wattana – Petcha Kasem Road (Heading to Petcha Kasem 69)

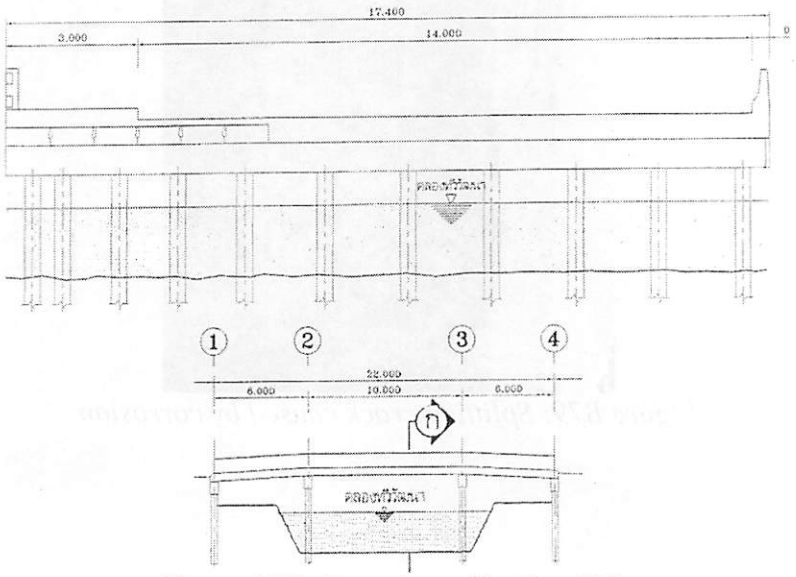


Figure B77: Drawing of bridge #25

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC

Slab : Cast-in-Situ RC

Observed Deterioration:

Pier : Water Leakage, Change of Surface Color, Splitting

Beam : Shrinkage, Bearing Pad

Slab : No Damage

Deterioration Level: 1

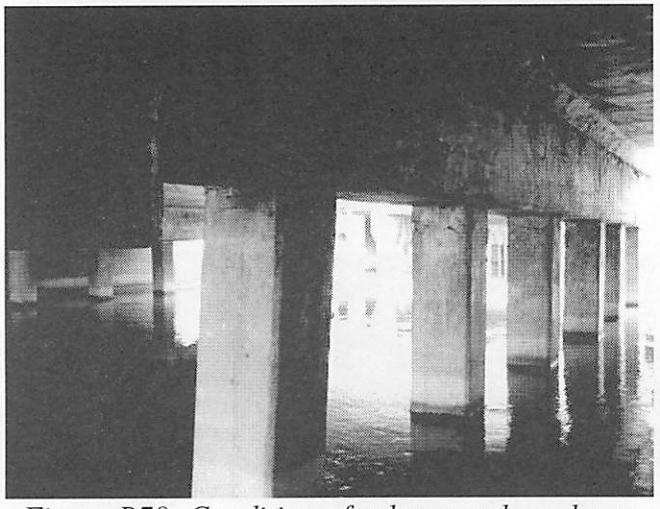


Figure B78: Condition of column and cap beam

Figure B79: Splitting crack caused by corrosion

Figure B80: Spalling with corrosion

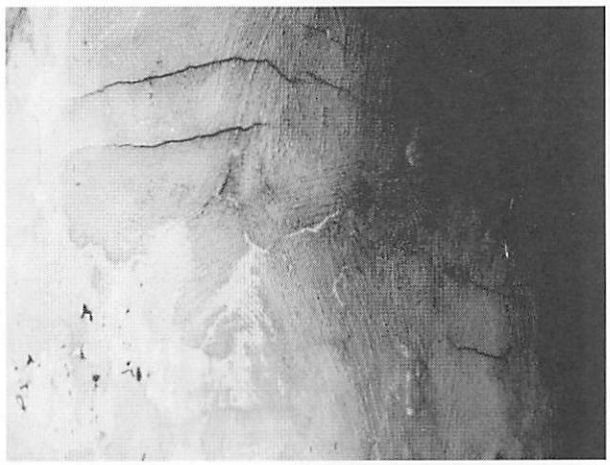


Figure B81: Shrinkage crack in previously repaired portion

26. Thawi Wattana Canal – Petcha Kasem Road (Heading to Petch Kasem 104)

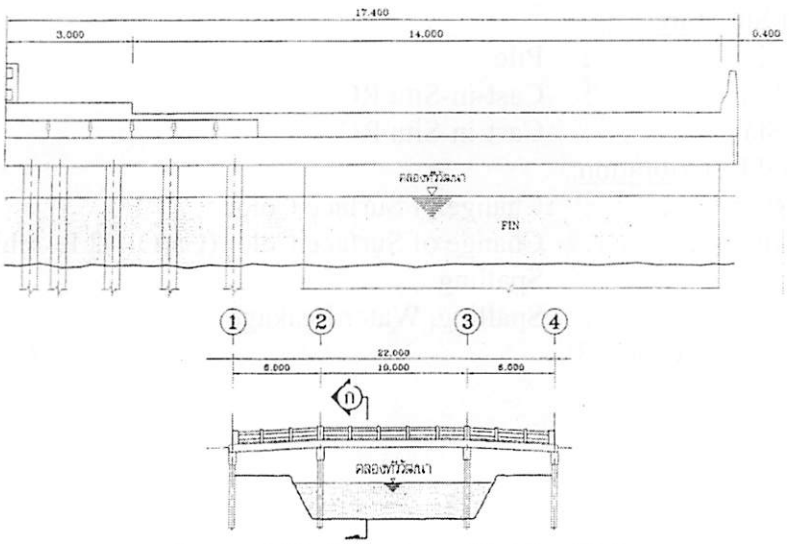


Figure B82: Drawing of bridge #26

Type of Structure:

Pier : Pile

Beam : Cast-in-Situ RC
Slab : Cast-in-Situ RC

Observed Deterioration:
Pier : N/A
Beam : Existence of Rust, Change of Surface Color, Cracks, Bearing Pad
Slab : N/A

Deterioration Level: 2

27. Yai Teab Canal – Petcha Kasem Road (Heading to Tha Phra Intersection)

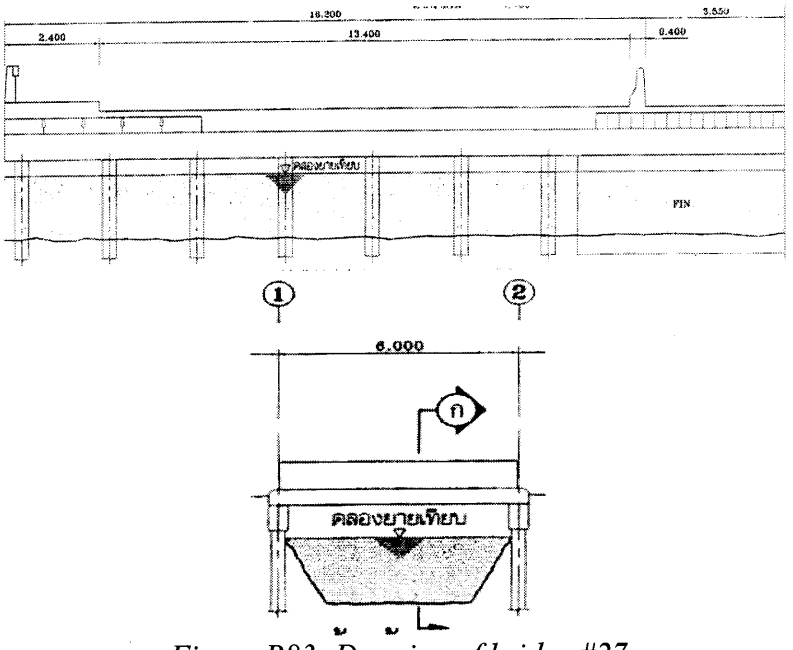


Figure B83: Drawing of bridge #27

Type of Structure:
Pier : Pile
Beam : Cast-in-Situ RC
Slab : Cast-in-Situ RC

Observed Deterioration:
Pier : Change of Surface Color
Beam : Change of Surface Color (Ca(OH)2 Leaching), Spalling
Slab : Spalling, Water Leakage

Deterioration Level: 3

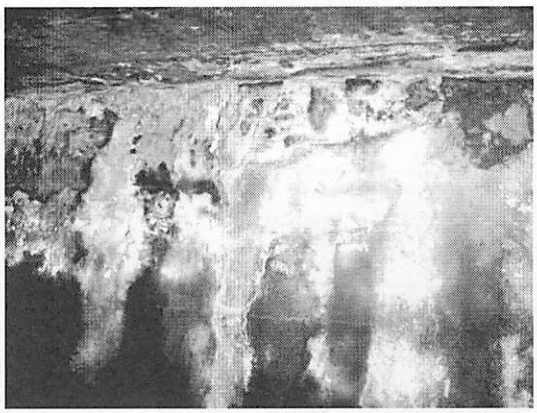


Figure B84: Leaching on the wall (caused by leakage of water)

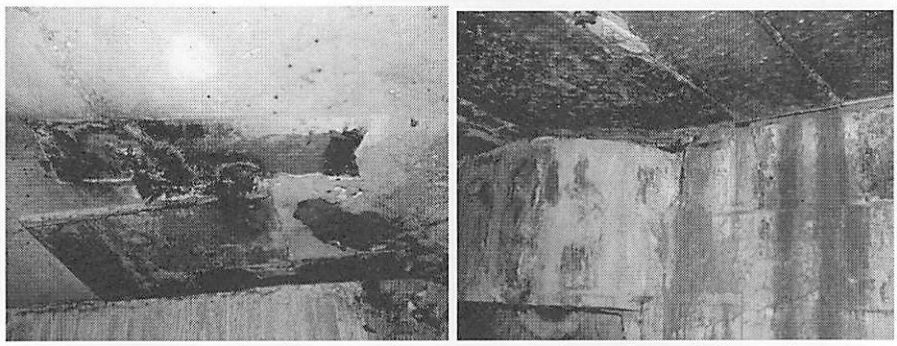


Figure B85: Spalling and water trace found on slab surface

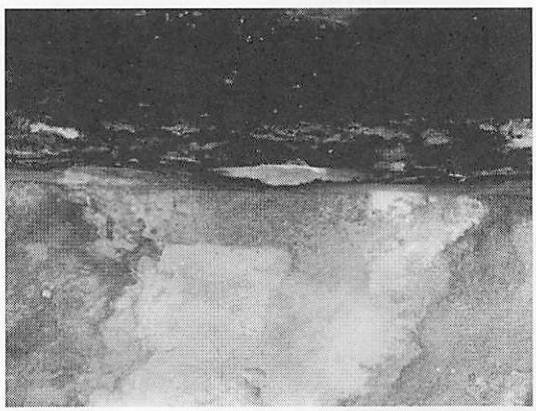


Figure B86: Condition of bearing rubber plate

Figure B87: Condition of the wall

28. Yai Teab Canal – Petcha Kasem Road (Heading to Bang Khae Intersection)

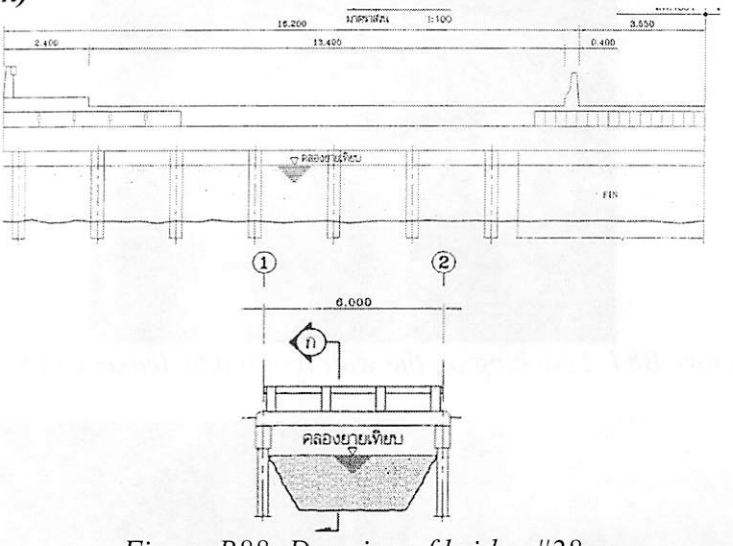


Figure B88: Drawing of bridge #28

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Impact,
Beam	:	Existence of Rust, Change of Surface Color, Cracks
Slab	:	Spalling, Corrosion

Deterioration Level: 3

Note : Spalling and severe cracking was observable near sewage pipe

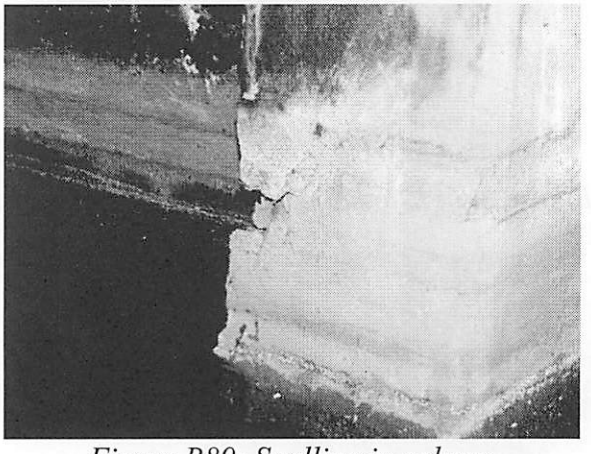


Figure B89: Spalling in column

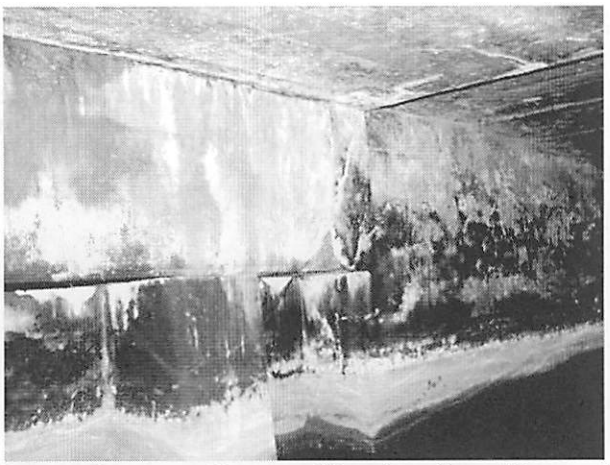


Figure B90 : Rust color as well as spalling has found in cap beam and slab

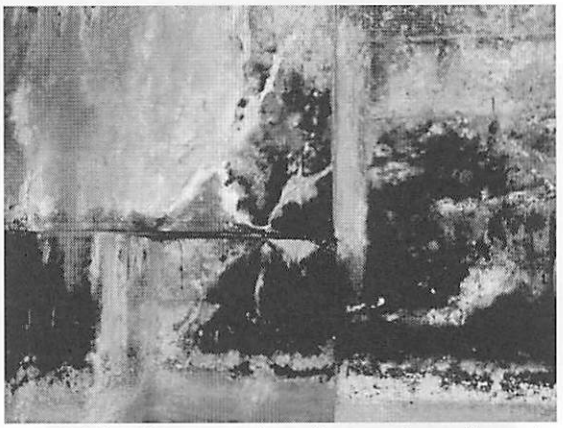


Figure B91: Change of surface color of cap beam

29. Bang Wa Canal – Petcha Kasem Road (Heading to Tha Phra Intersection)

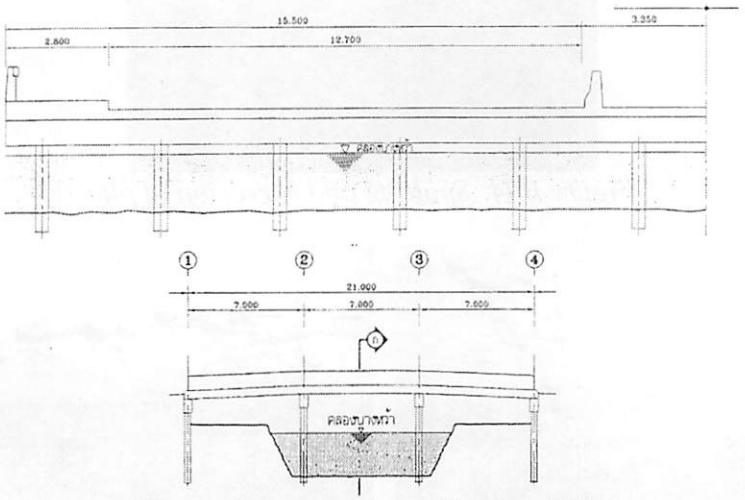


Figure B92: Drawing of bridge # 29

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Change of Surface Color
Beam	:	Spalling, Corrosion, Water Leakage
Slab	:	Spalling, Corrosion, Honeycombs, Water Leakage

Deterioration Level: 4

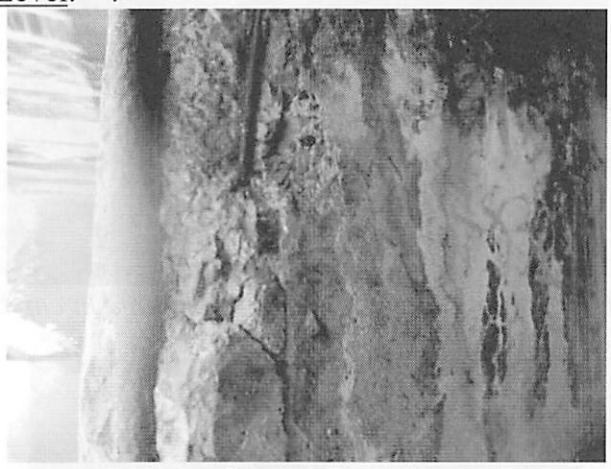


Figure B93: Spalling and corrosion of column

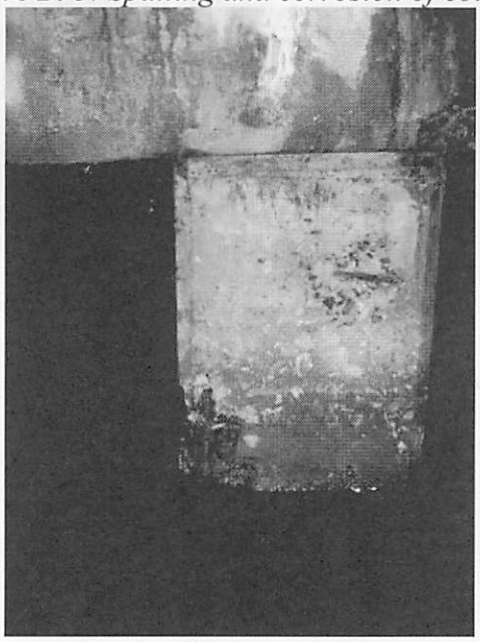


Figure B94: Spalling and corrosion of pile

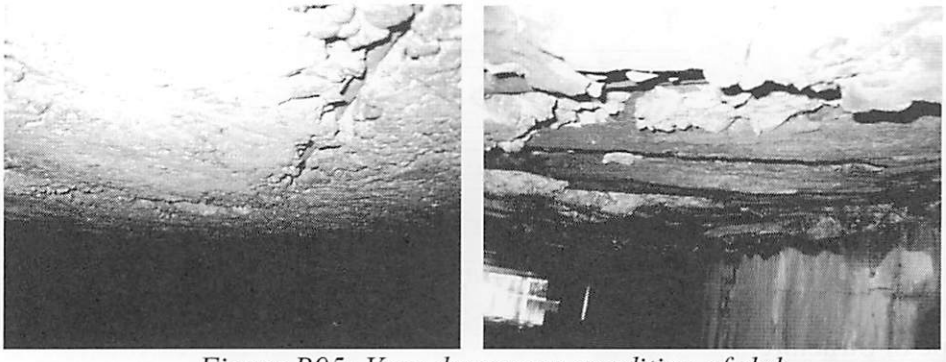


Figure B95: Very dangerous condition of slab

30. Bang Wa Canal – Petcha Kasem Road (Heading to Bang Khae Intersection)

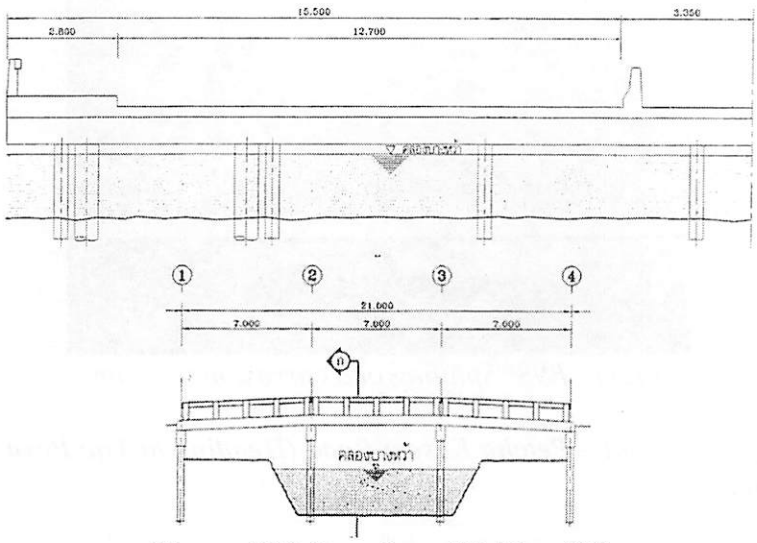


Figure B96:Drawing of Bridge #30

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Change of Surface Color
Beam	:	Spalling, Corrosion, Water Leakage, Change of Surface Color
Slab	:	Spalling, Corrosion, Honeycombs, Water Leakage

Deterioration Level: 3

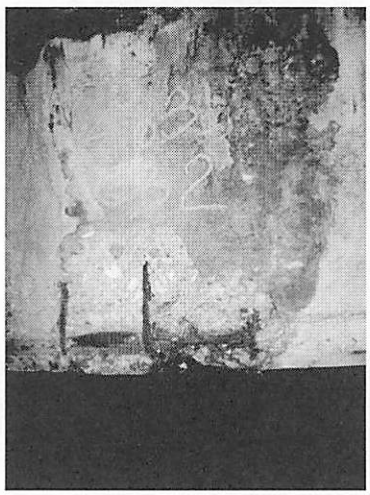


Figure B97: Spalling and corrosion in wide area

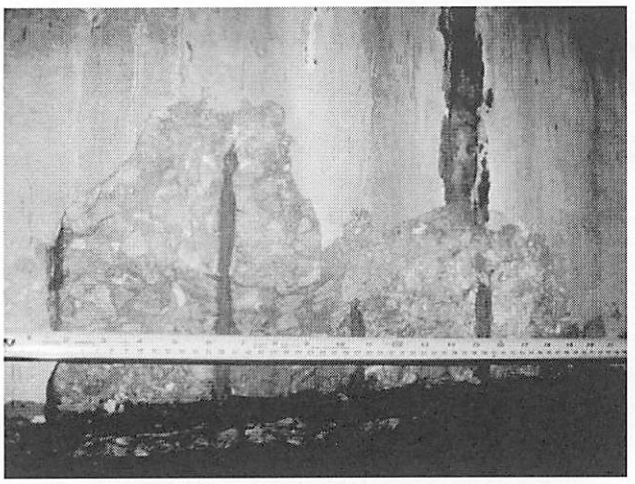


Figure B98: Spalling and corrosion in beam

31. Rong Yao Canal – Petcha Kasem Road (Heading to Tha Phra Intersection)

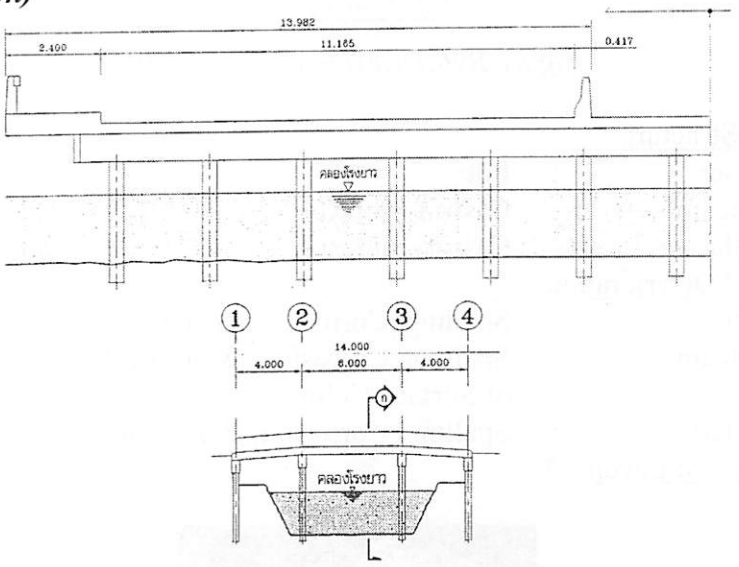


Figure B99: Drawing of bridge #31

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion
Beam	:	Spalling, Corrosion, Water Leakage
Slab	:	Spalling, Corrosion, Change of Surface Color, Water Leakage

Deterioration Level: 4

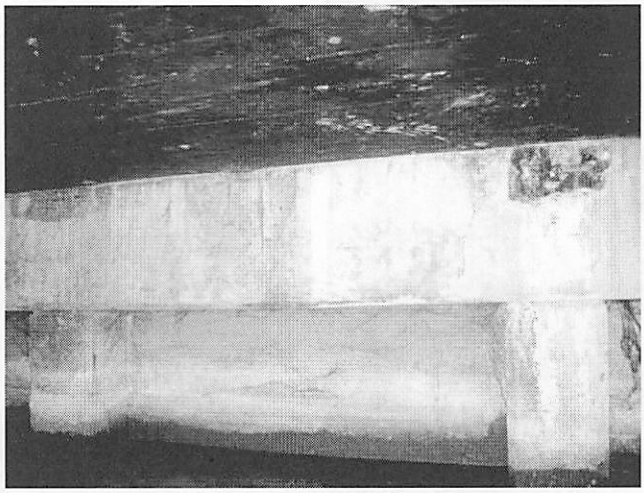


Figure B100: General view of cap beam and pier

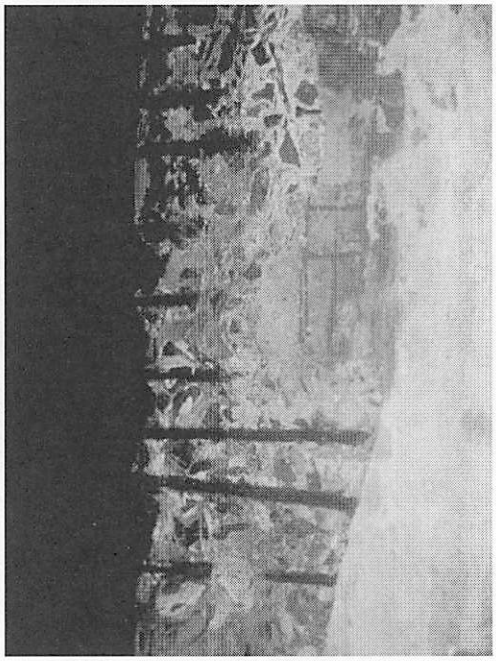


Figure B101: Concrete spalling by corrosion

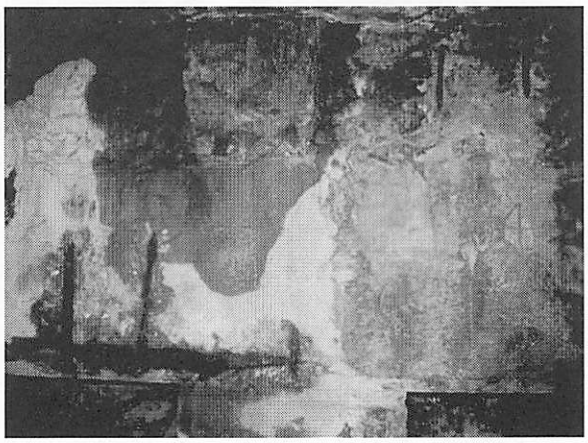


Figure B102: Extensive corrosion in cap beam

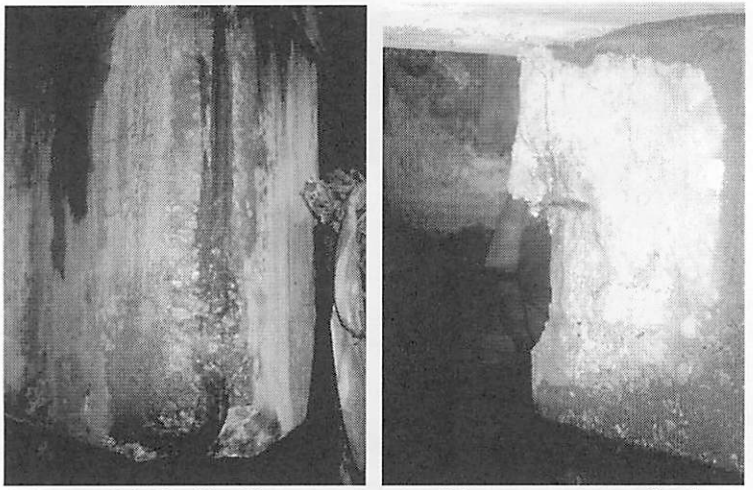


Figure B103: Spalling-out caused by corrosion of rebar

Figure B104: Corrosion and spalling in slab

32. Rong Yao Canal – Petcha Kasem Road (Heading to Bang Khae Intersection)

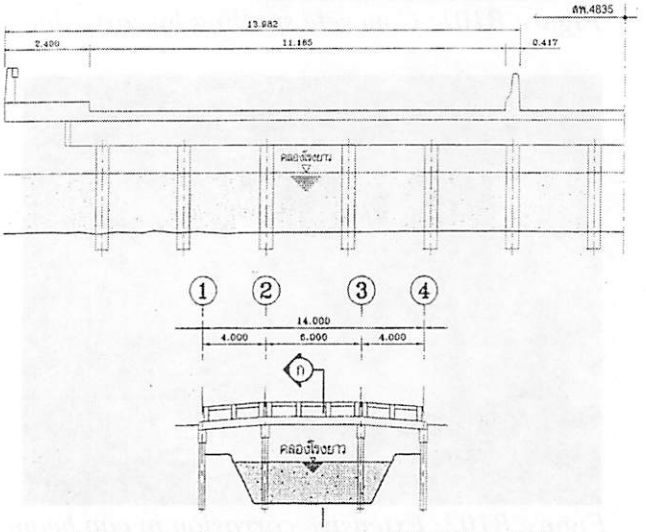


Figure B105: Drawing of bridge #32

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

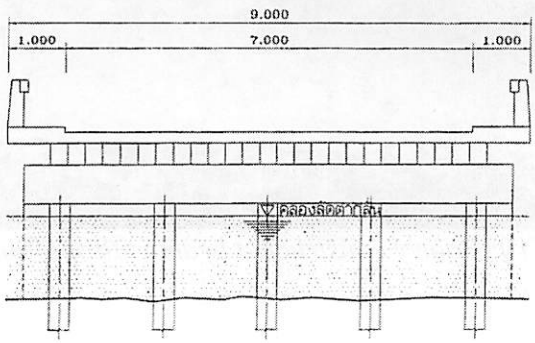
Pier	:	N/A
Beam	:	Spalling, Corrosion, Water Leakage
Slab	:	Spalling, Corrosion, Change of Surface Color, Water Leakage

Deterioration Level: 3

Figure B106: Corrosion and trace of water leakage

Figure B107: Small spalling as well as shrinkage crack in cap beam

33. Lat Ta glan Canal – Charan Sanitwong Soi 13 (Heading to Ratcha Pruek Rd.)



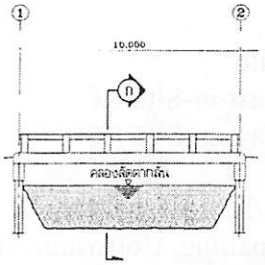


Figure B108: Drawing of bridge #33

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Concentrated Load (Wall)
Beam	:	Spalling, Corrosion, Water Leakage, Small Covering Depth
Slab	:	Spalling, Corrosion, Water Leakage, Small Covering Depth

Deterioration Level: 3

Figure B109: Damage caused by poor load

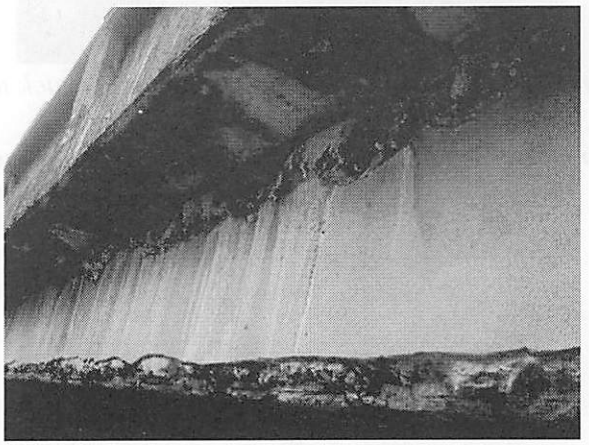


Figure B110: Poorly constructed beam with spalling problem

34. Lat Wat Chim Canal – Charan Sanitwong Soi 13 (Heading to Ratcha Pruek Rd.)

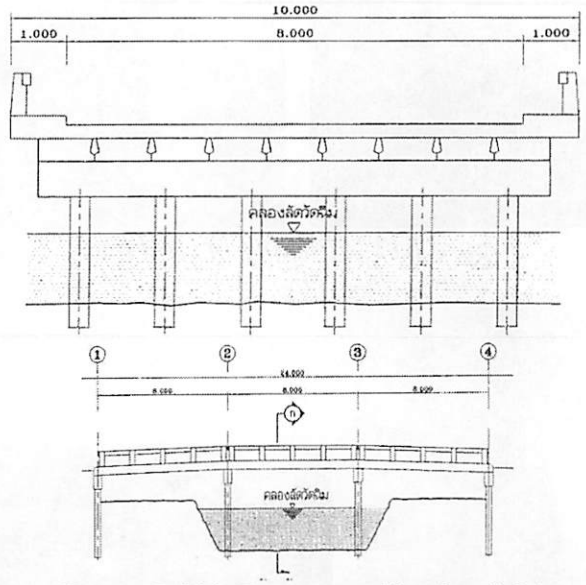


Figure B111: Drawing of bridge # 34

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Change of Surface Color, Plywood
Beam	:	Change of Surface Color, Spalling, Small Covering,Honeycomb
Slab	:	Spalling, Corrosion, Water Leakage, Small Covering Depth, Rubbish

Deterioration Level: 2

Figure B112: Plywood found at the connection with cap beam

Figure B113: Rusting of steel bars

Figure B114: Water leakage at the joint inducing accelerated corrosion

35. Sarn Jao Canal – Charan Sanitwong Soi 13 (Heading to Ratcha Pruek Rd.)

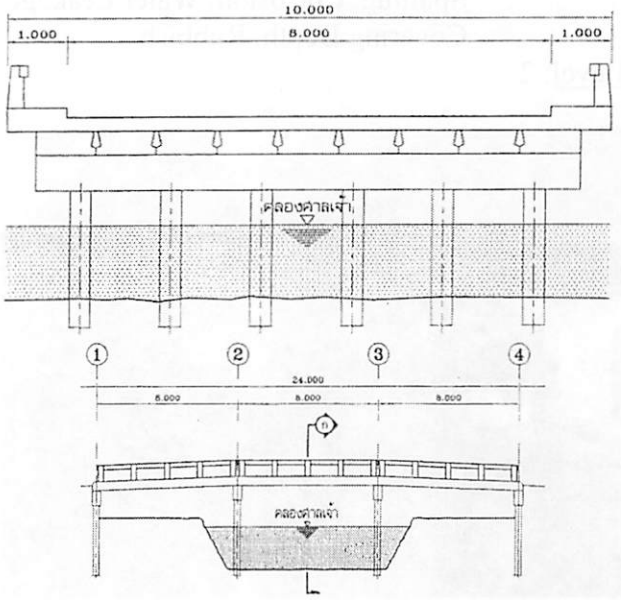


Figure B115: Drawing of bridge #35

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Precast RC

Observed Deterioration:

Pier	:	Crack caused by Concentrated Load
Beam	:	Spalling
Slab	:	Spalling, Corrosion, Water Leakage

Deterioration Level: 2

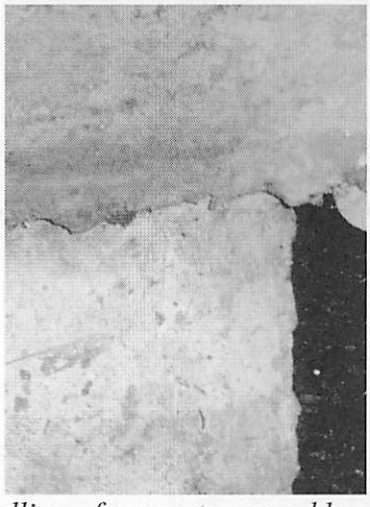


Figure B116: Spalling of concrete caused by concentrated load

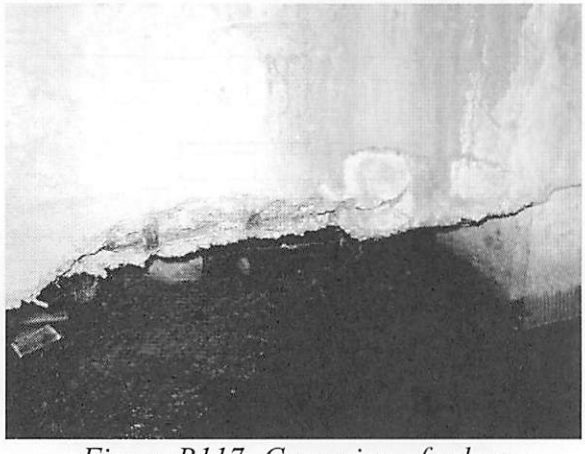


Figure B117: Corrosion of rebar

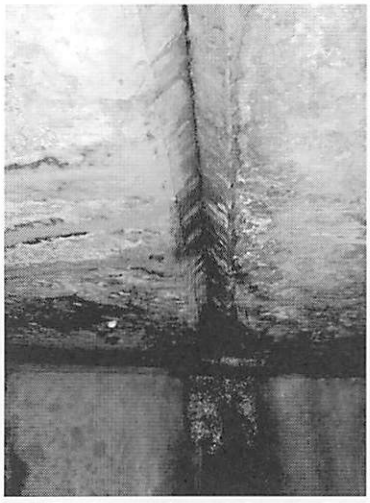


Figure B118: Water leakage through gap between precast slab

36. Ta Node Canal – Charan Sanitwong Soi 13 (Heading to Charan Sanitwong Rd.)

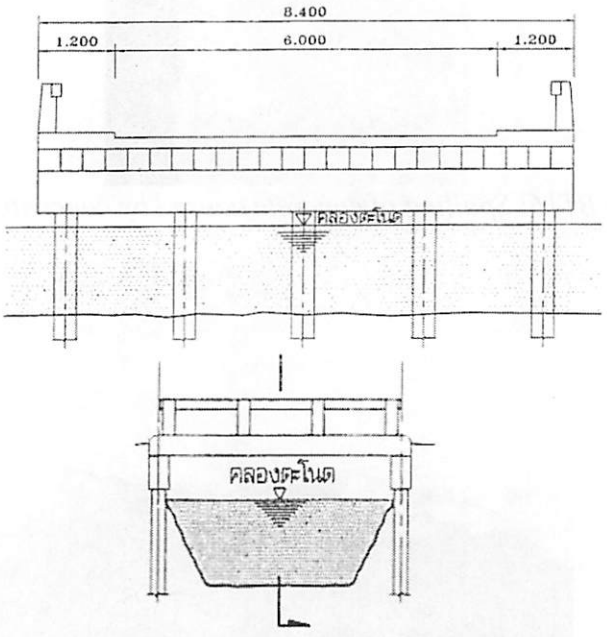


Figure B119: Drawing of bridge #36

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A, Honeycombs
Beam	:	Change of Surface Color
Slab	:	No Damage

Deterioration Level: 1

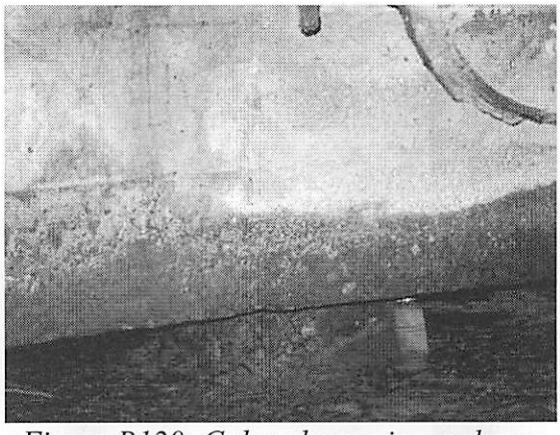


Figure B120: Color change in cap beam

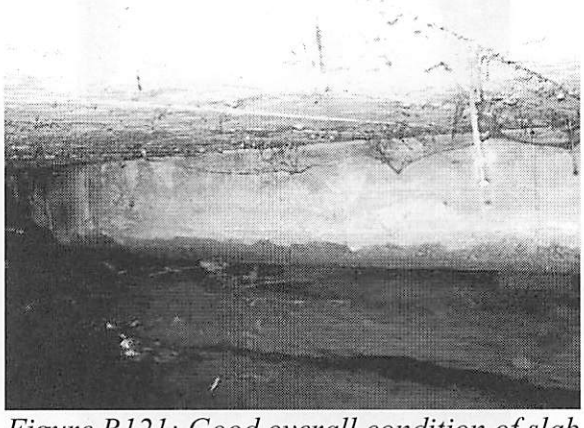


Figure B121: Good overall condition of slab

37. BangKok Yai Canal – Charan Sanitwong Soi 13 (Heading to Charan Sanitwong Rd.)

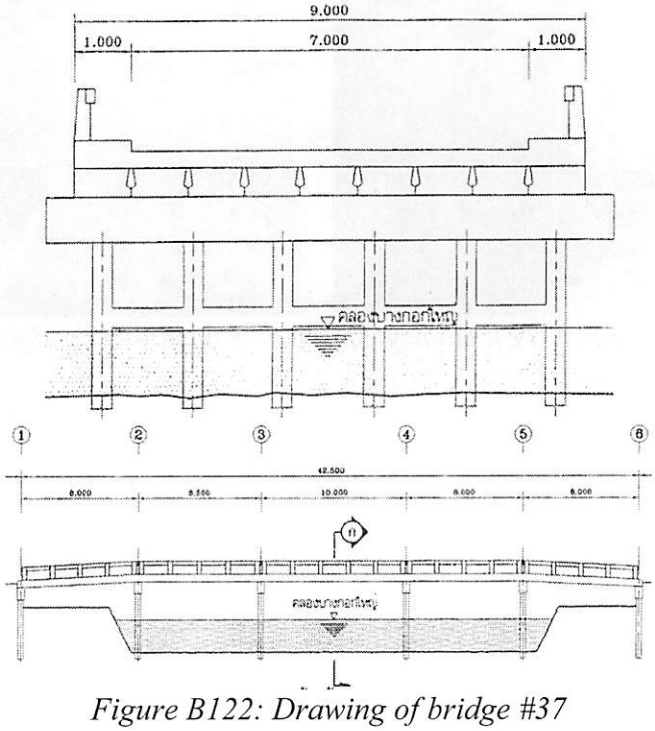


Figure B122: Drawing of bridge #37

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Honeycombs, Erosion
Beam	:	Honeycombs, Covering Depth, Erosion
Slab	:	Spalling, Corrosion

Deterioration Level: 2

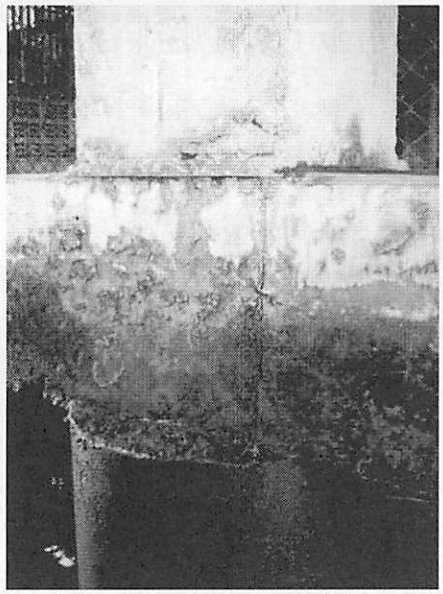


Figure B123: Honeycombs, erosion, and change of surface color

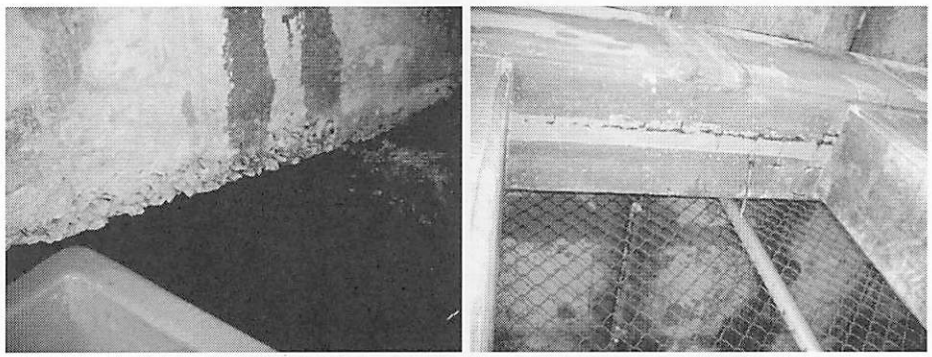


Figure B124: Poorly constructed portion of bridge

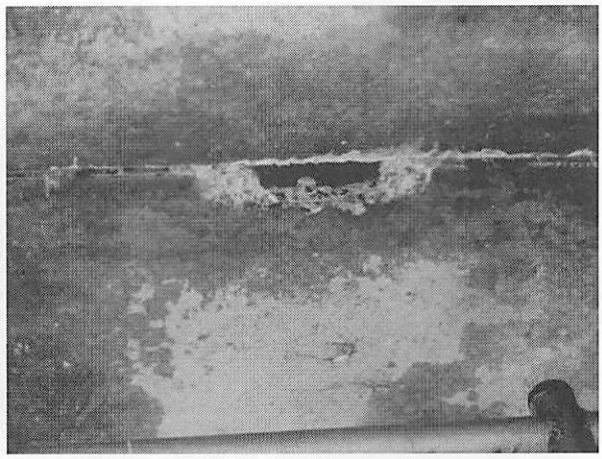


Figure B125: Spalling of concrete

38. Lad Mayom Canal – Charan Sanitwong Soi 35 (Heading to Buddha #1 Rd.)

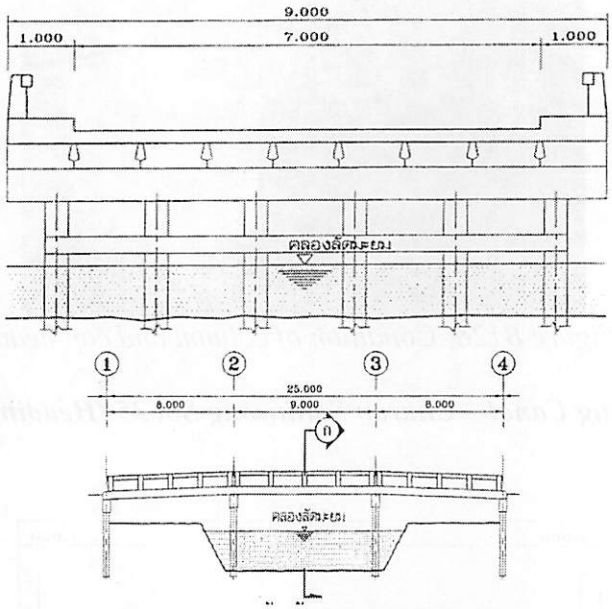


Figure B126: Drawing of bridge

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Small Spalling with previous patching, Honeycombs
Beam	:	Change of Surface Color
Slab	:	Change of Surface Color

Deterioration Level: 1

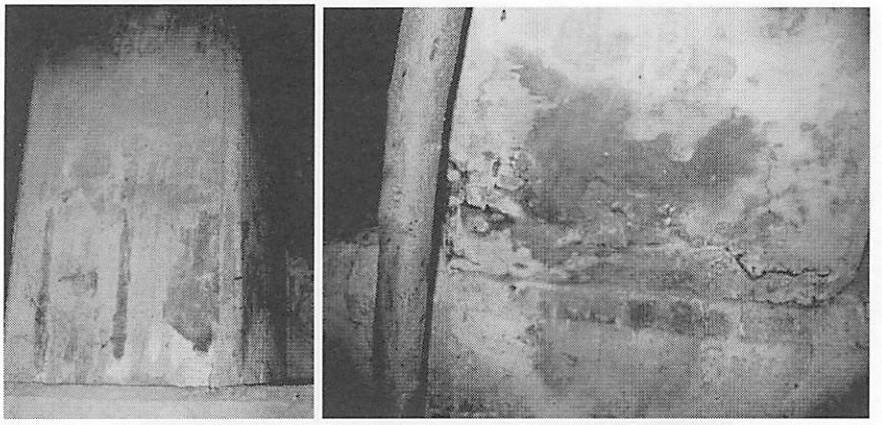


Figure B127: Honeycombs, spalling and trace of internal corrosion

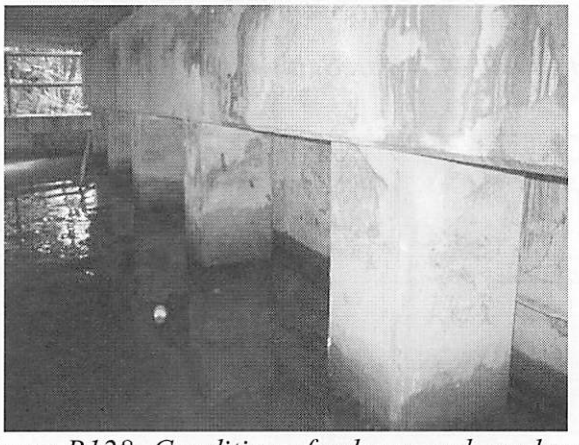


Figure B128: Condition of column and cap beam

39. Lam Padong Canal – Charan Sanitwong Soi 35 (Heading to Buddha #1 Rd.)

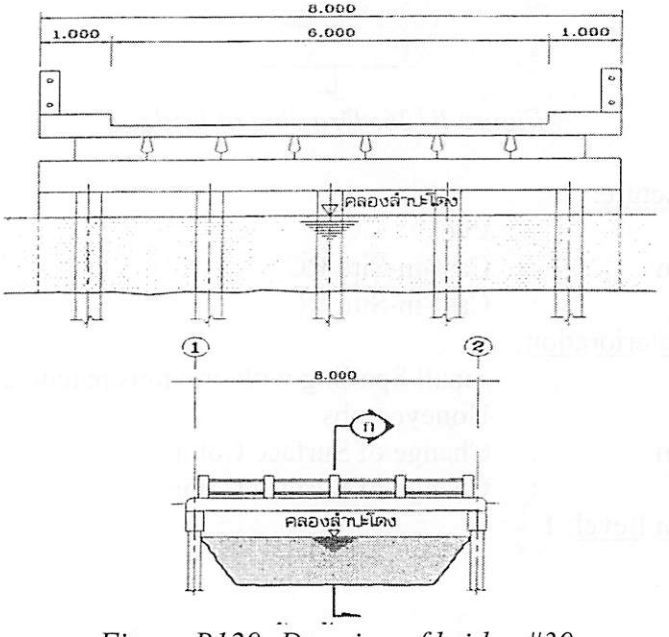


Figure B129: Drawing of bridge #39

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Cracks
Beam	:	Change of Surface Color, Erosion, Water Leakage, Segregation
Slab	:	No Damage

Deterioration Level: 1

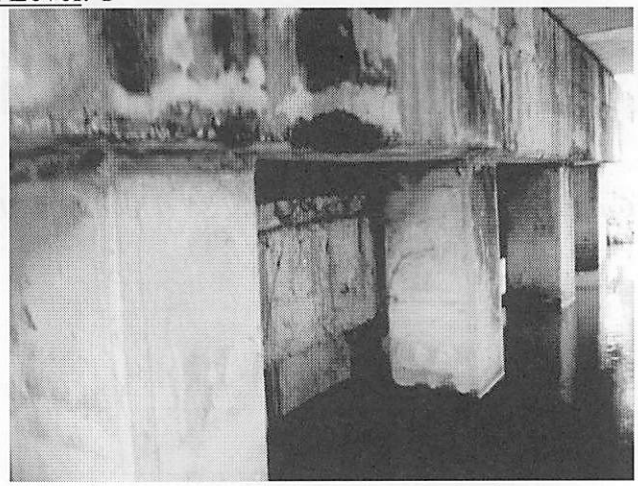


Figure 130: Trace of water leakage

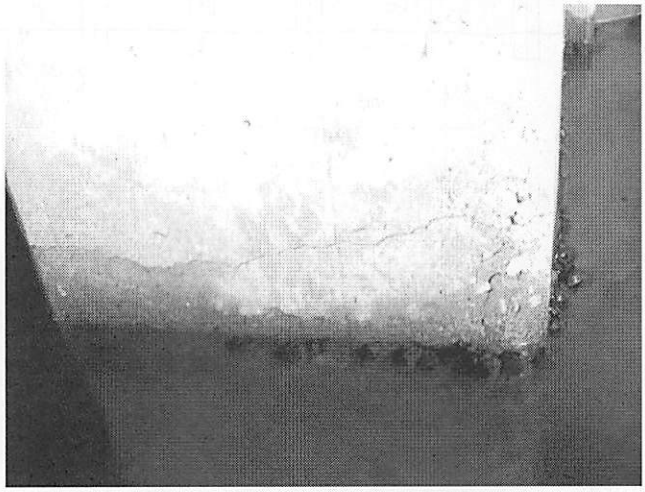


Figure B131: Small crack with honeycombs

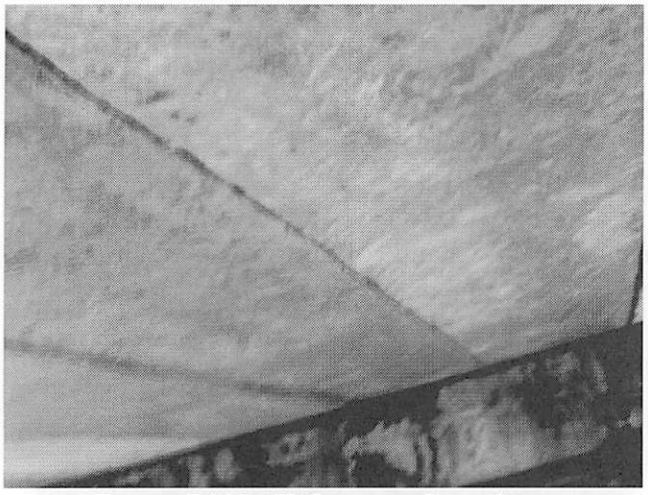


Figure B132: Slab in good condition

40. No name Canal – Charan Sanitwong Soi 35 (Heading to Buddha #1 Rd.)

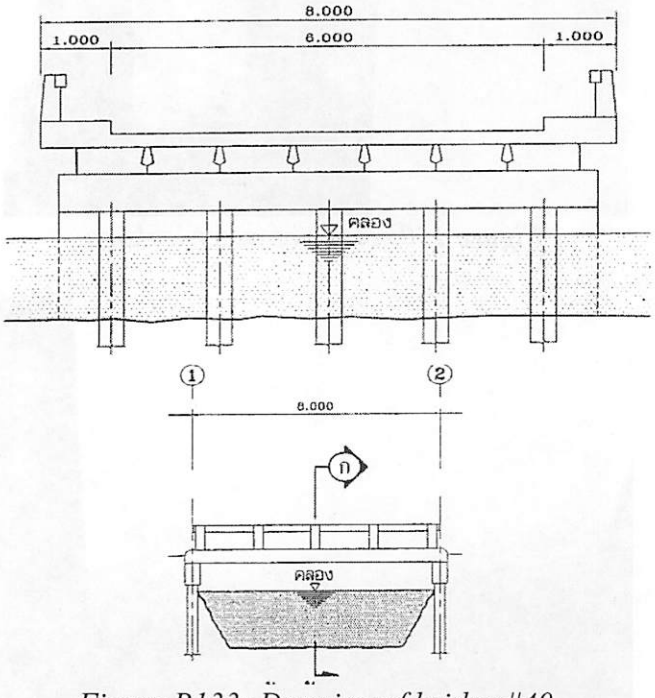


Figure B133: Drawing of bridge #40

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Beam	:	No Damage
Slab	:	Poor Construction

Deterioration Level: 1

41. No name canal – Charan Sanitwong Soi 35 (Heading to Ratch Preuk Rd)

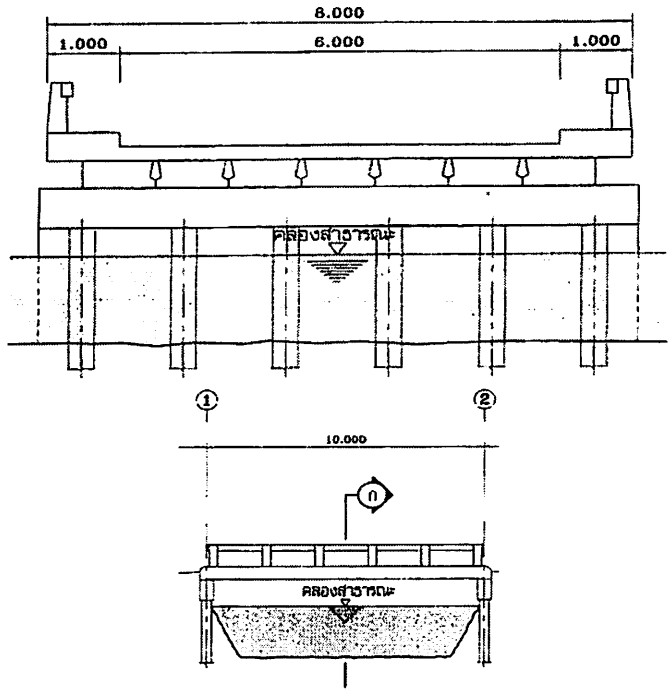


Figure B134: Drawing of bridge #41

Type of Structure:

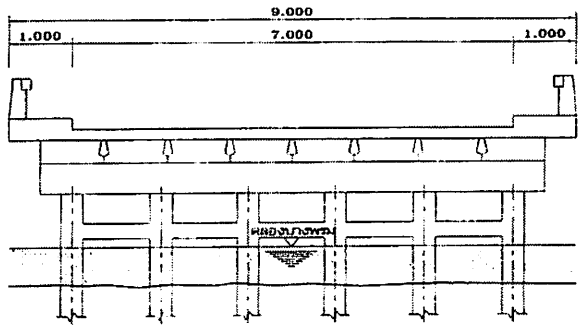
Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Beam	:	Spalling, Poor Construction
Slab	:	No Damage

Deterioration Level: 1

42. Bang Phrom Canal –Charan Sanitwong Soi 35 (Heading to Wat Kaew–Buddha #1 Rd.)



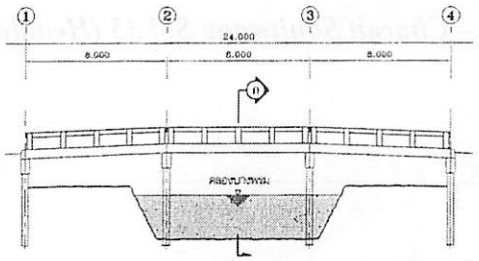


Figure B135: Drawing of bridge #42

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Incline, Change of Surface Color, Segregation, Spalling, Corrosion
Beam	:	Spalling, Corrosion,Honeycombs, Change of Surface Color
Slab	:	No Damage

Deterioration Level: 4

Figure B136: Badly-shaped column

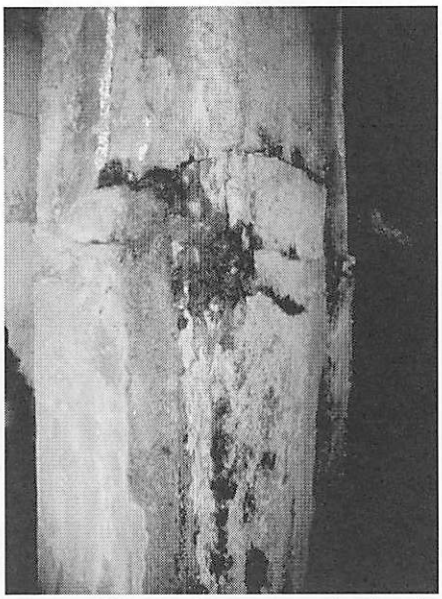


Figure B137: Inclining cracked column

Figure B138: Small spalling caused by corrosion

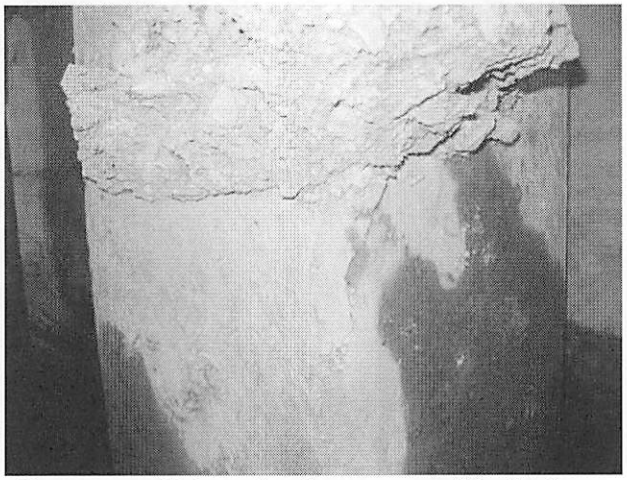


Figure B139: Severe condition of column caused by bad construction work

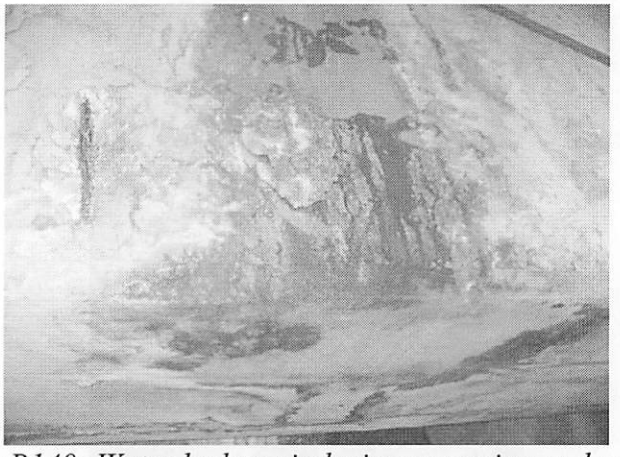


Figure B140: Water leakage inducing corrosion and spalling

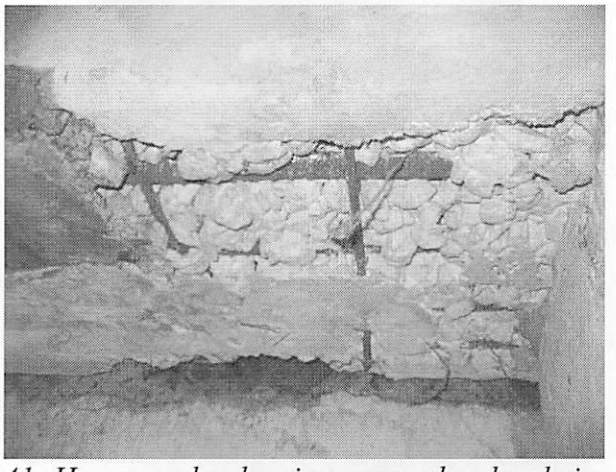


Figure B141: Honeycombs showing exposed re-bar being corroded

43. No name canal – Charan Sanitwong Soi 35 (Heading to Ratcha Pruek Rd)

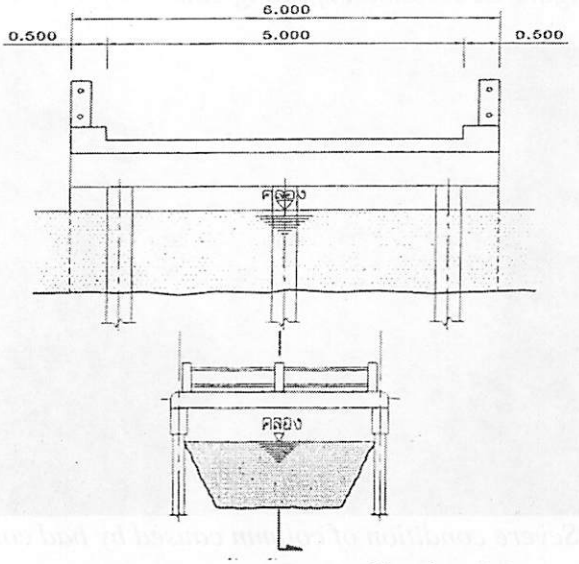


Figure B142: Drawing of bridge #43

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Erosion, Spalling, Corrosion (Retaining Wall)
Beam	:	Spalling, Corrosion, Water Leakage
Slab	:	Poor Construction (Cement Bag)

Deterioration Level: 2

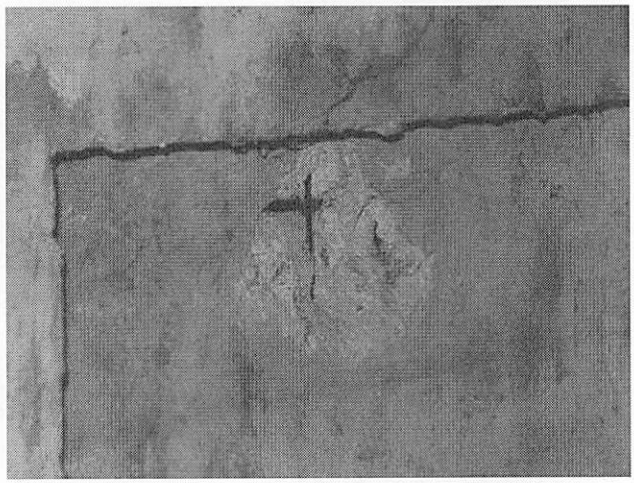


Figure B143: Corrosion leading to spalling out

Figure B144: Trace of water leakage and surface color change

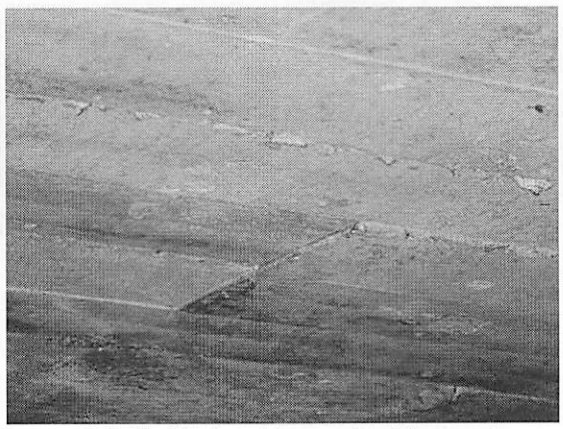


Figure B145: Slab with no significant damage

44. Lad Wat Mai Canal – Charan Sanitwong Soi 35 (Heading to Ratcha Pruek Rd)

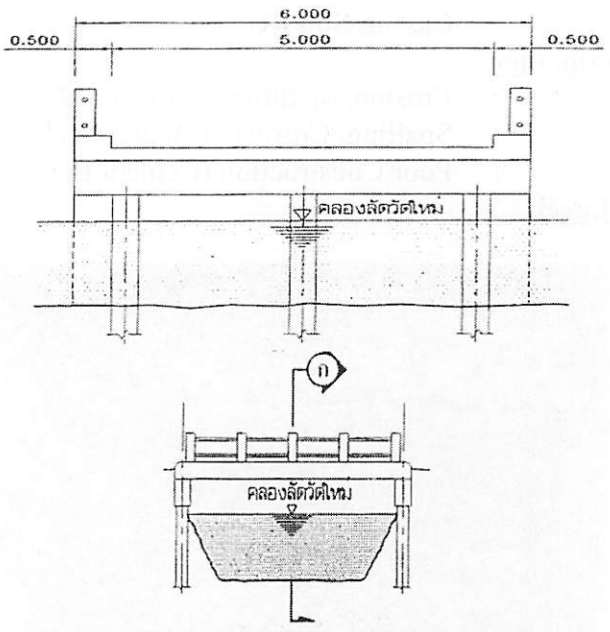


Figure B146: Drawing of bridge # 44

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Chage of Surface Color, Water Leakage
Beam	:	Chage of Surface Color, Water Leakage
Slab	:	Spalling, Corrosion

Deterioration Level: 2

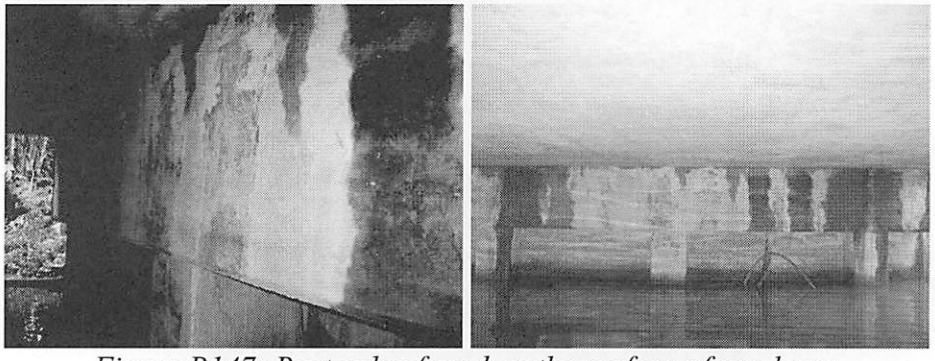


Figure B147: Rust color found on the surface of cap beam

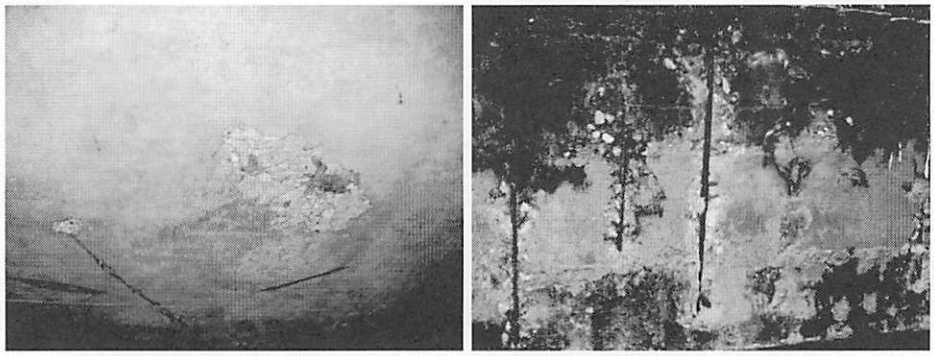


Figure B148: Corrosion (more severe at edge slab)

45. Lad Wat Saphan Canal – Charan Sanitwong Soi 35 (Heading to Ratcha Pruek Rd)

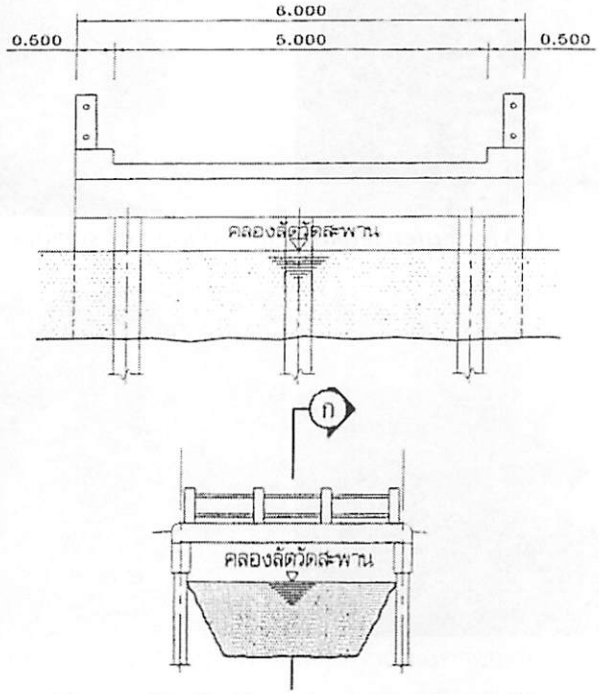


Figure B149: Drawing of bridge # 45

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Spalling, Corrosion
Beam	:	Spalling, Corrosion, Chage of Surface Color
Slab	:	Spalling, Corrosion, Poor Construction

Deterioration Level: 2

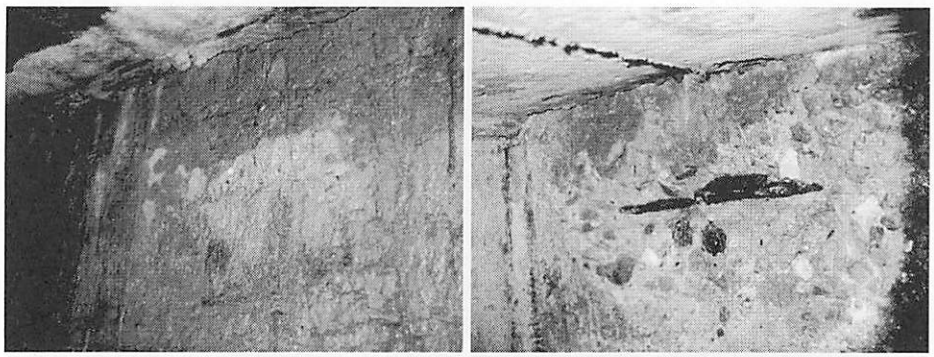


Figure B150: Corrosion in cap beam (color caused by carbonation test)

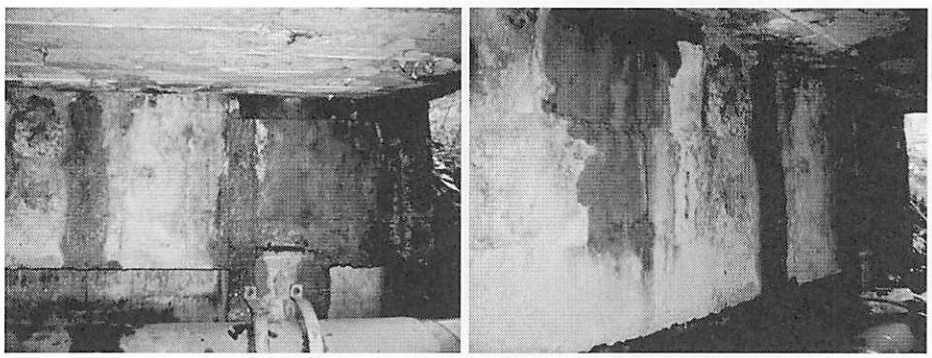
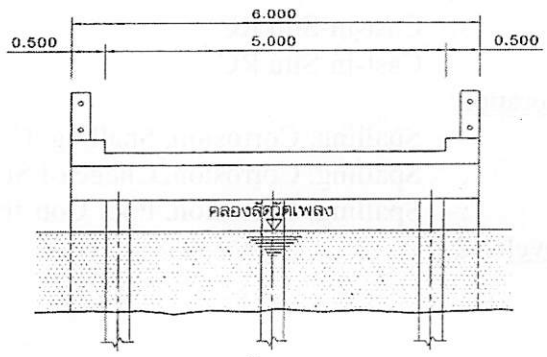


Figure B151: Water leakage and chage of surface color

Figure B152: Comparison between underneath slab and edge side slab

46. Lat Wat Phleng Canal – Charan Sanitwong Soi 35 (Heading to Ratcha Pruek Rd)



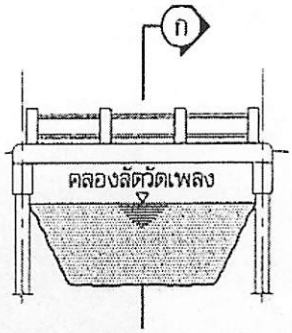


Figure B153: Drawing of bridge #46

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Aggregate, Spalling(Wall), Corrosion(Wall)
Beam	:	Spalling, Corrosion, Carbonation
Slab	:	Spalling, Corrosion, Small Covering Depth

Deterioration Level: 3

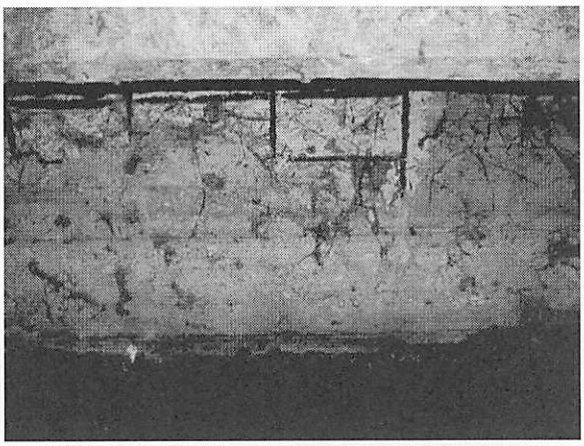


Figure B154: Corrosion of RC wall

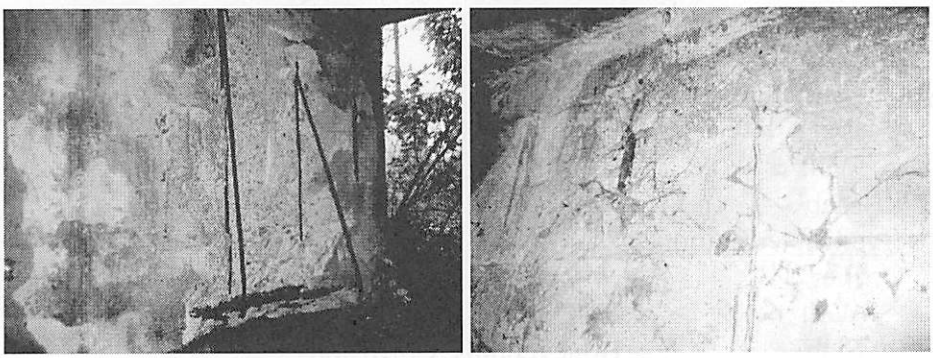


Figure B155: Condition of cap beam

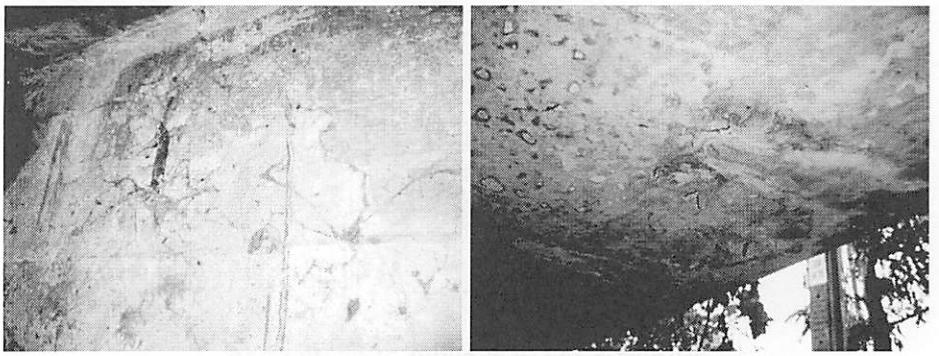


Figure B156: Condition of wall and slab

47. No Name Canal – Charan Sanitwong Soi 35 (Heading to Ratcha Pruek Rd)

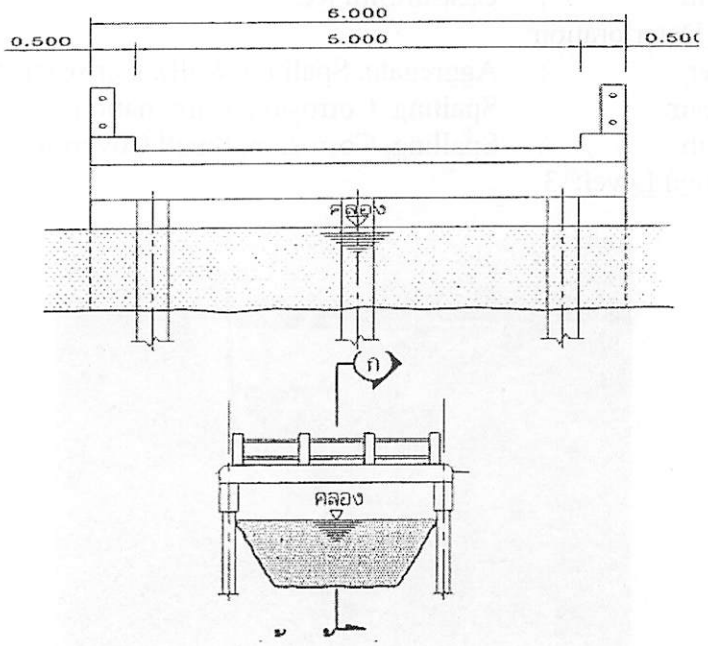


Figure B157: Drawing of bridge #47

Type of Structure:

Pier	:	Pile
Wall	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	N/A
Wall	:	No Damage
Slab	:	Honeycombs, Corrosion

Deterioration Level: 2

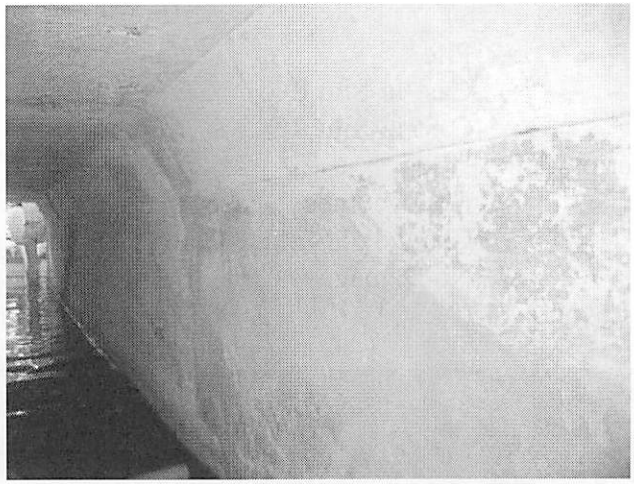


Figure B158: Wall in good condition

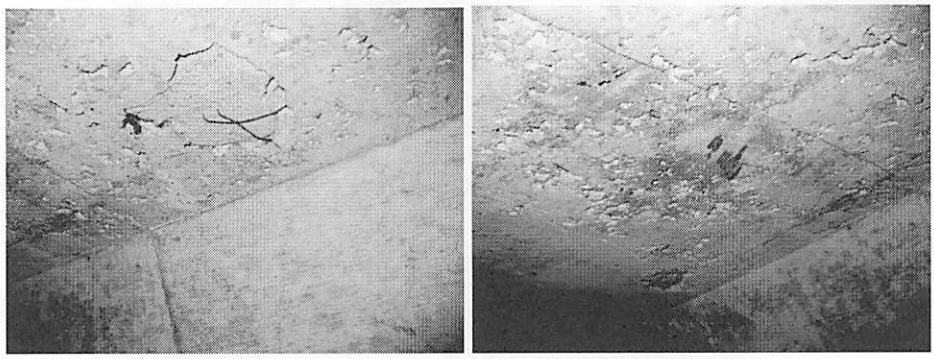


Figure B159: Unwanted objects embeded in slab

48. Lat Thom Ya Canal – Charan Sanitwong Soi 35 (Heading to Charan Sanitwong 35)

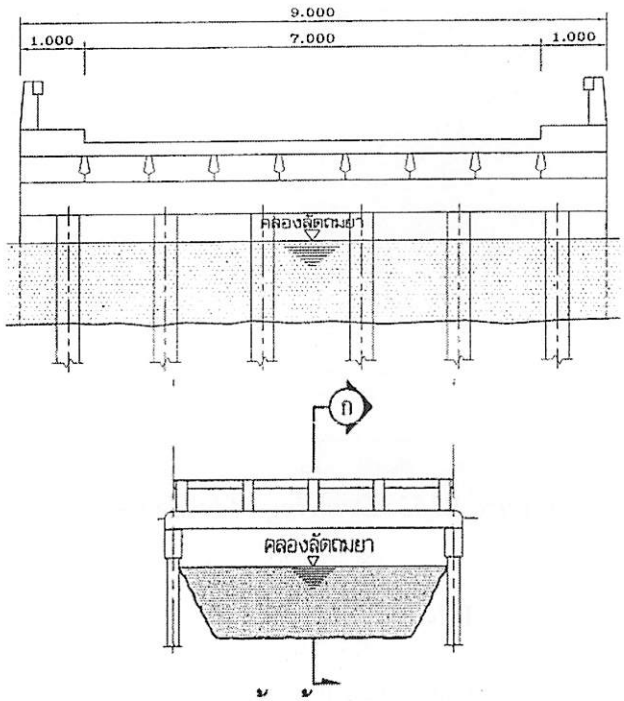


Figure B160: Drawing of bridge # 48

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Honeycombs
Beam	:	Change of Surface Color, Spalling
Slab	:	No Damage

Deterioration Level: 2

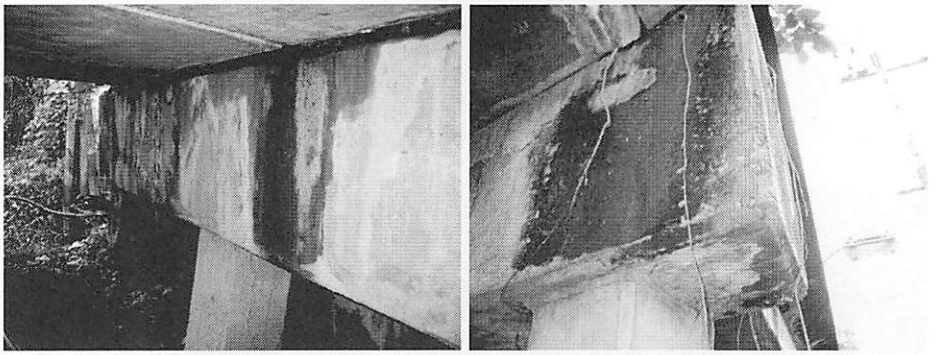


Figure B161: Water leakage initiating corrosion

49. Wat Kaew Canal – Charan Sanitwong Soi 35 (Heading to Charan Sanitwong Rd)

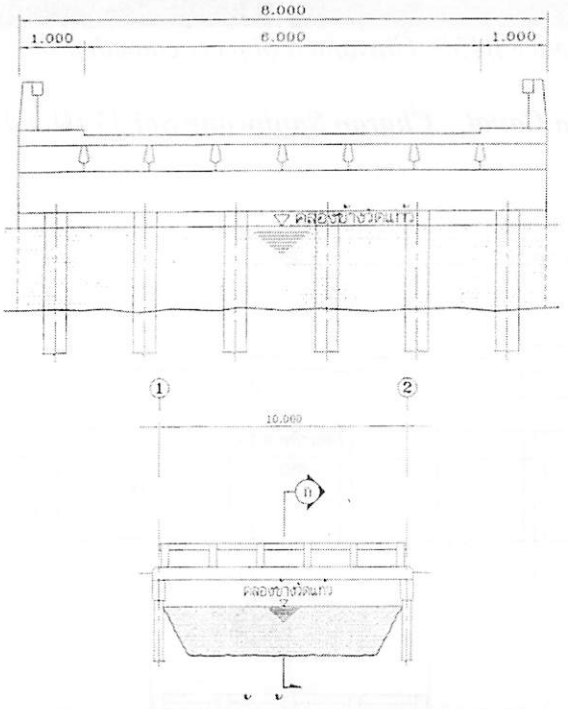


Figure B162: Drawing of bridge # 49

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier : No Damage
Beam : No Damage
Slab : No Damage

Deterioration Level: 1

50. Bang Phrom Canal – Charan Sanitwong Soi 35 (Heading to Barom Rat Chonnanee Rd)

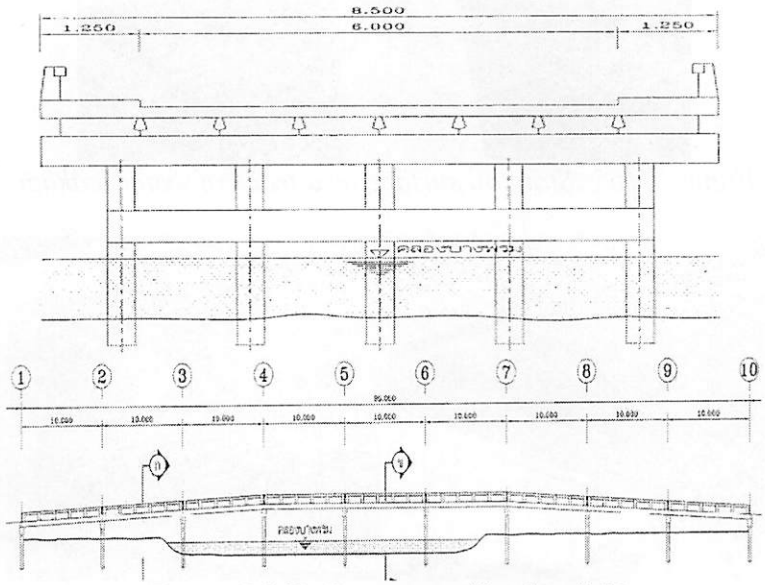


Figure B163: Drawing of bridge # 50

Type of Structure:

Pier : Pile
Beam : Cast-in-Situ RC
Slab : Cast-in-Situ RC

Observed Deterioration:

Pier : Change of Surface Color, Surface Erosion
Beam : Change of Surface Color
Slab : Spalling, Corrosion, Water Leakage, Change of Surface Color

Deterioration Level: 1

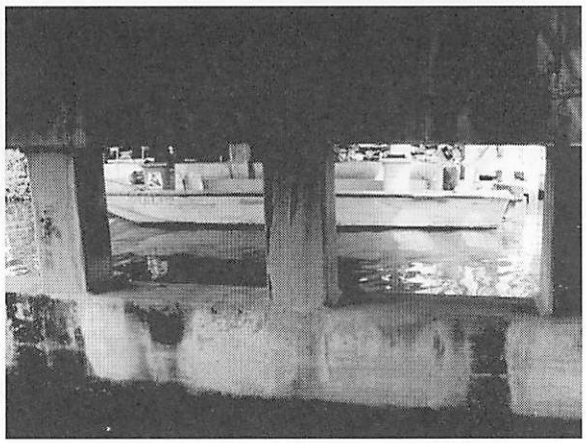


Figure B164: Change of surface color with erosion of some portion

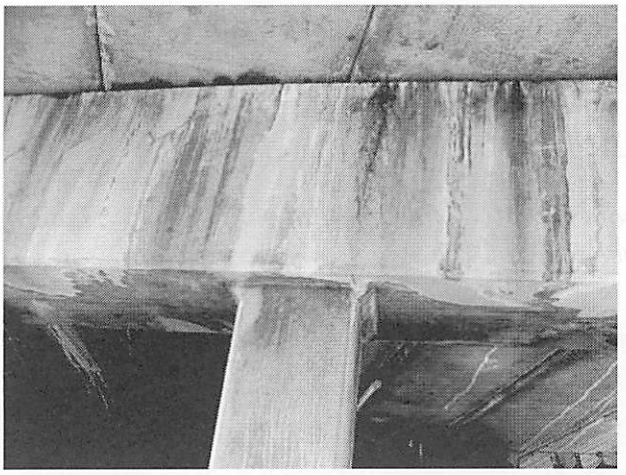


Figure B165: Stain on surface as a trace of water leakage

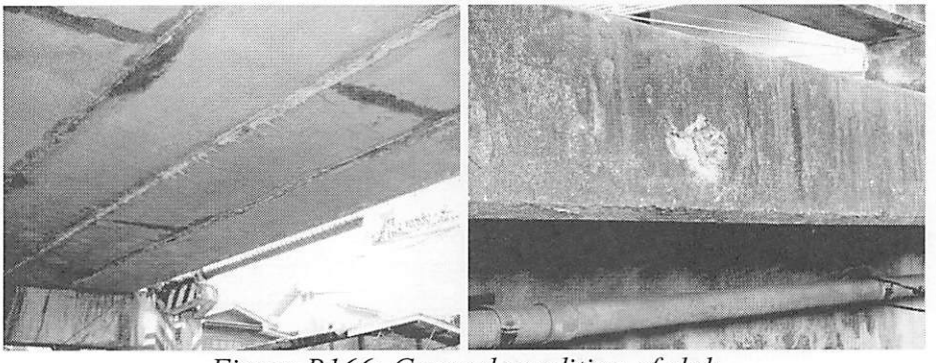


Figure B166: General condition of slab

51. Shak Phra Canal – Bang Khun Non Road (Heading to Charan Sanitwong Rd.)

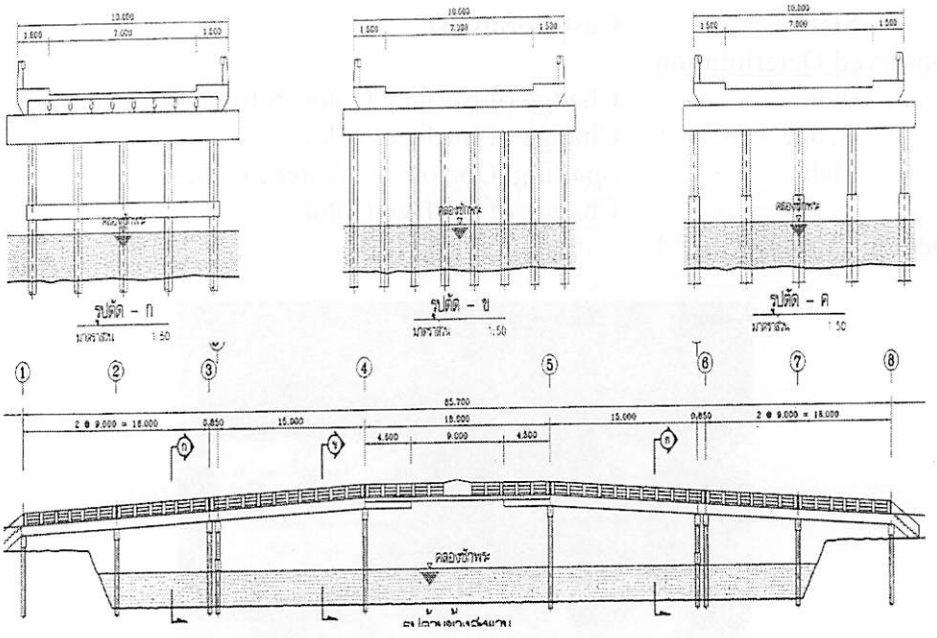


Figure B167: Drawing of bridge # 51

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Girder	:	Pre-Cast Concrete Girder
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Structural Crack, Surface Erosion, Honeycombs
Beam	:	Spalling, Corrosion, Change of Surface Color
Girder	:	Spalling, Corrosion, Change of Surface Color
Slab	:	Spalling, Corrosion, Change of Surface Color

Deterioration Level: 2

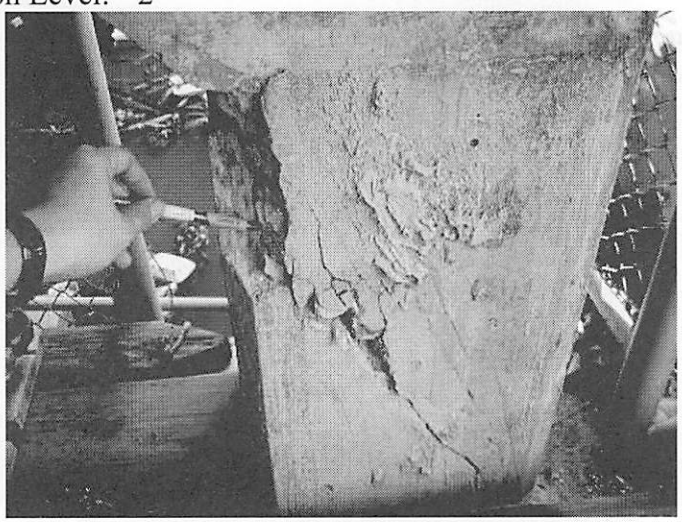


Figure B168: Structural failure of column

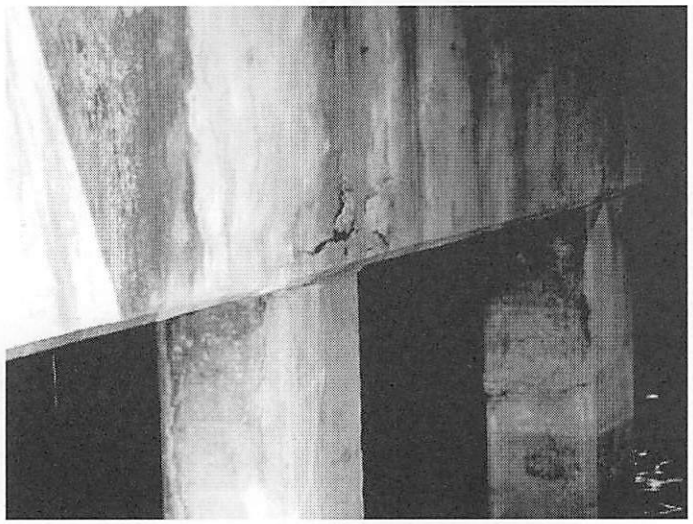


Figure B169: Defect in cap beam

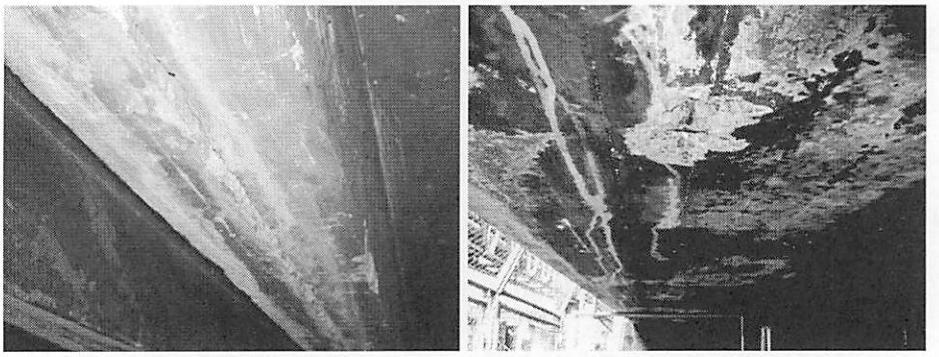


Figure B170: Corrosion of re-bar and spalling of concrete

52. Wat Chao Arm Canal - Bang Khun Non Road (Heading to Charan Sanitwong Rd.)

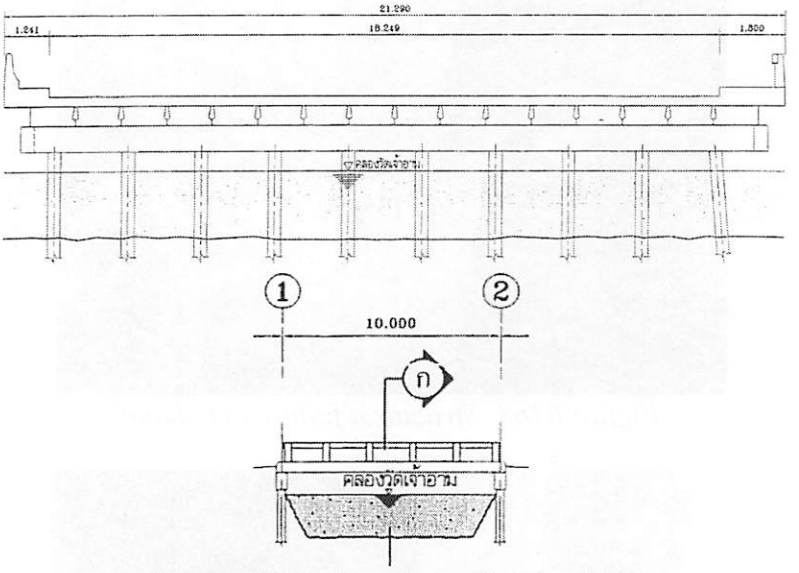


Figure B171: Drawing of bridge # 52

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Change of Surface Color, Erosion, Honeycombs (joint)
Beam	:	Spalling, Corrosion, Change of Surface Color, Honeycombs
Slab	:	Water Leakage

Deterioration Level: 2

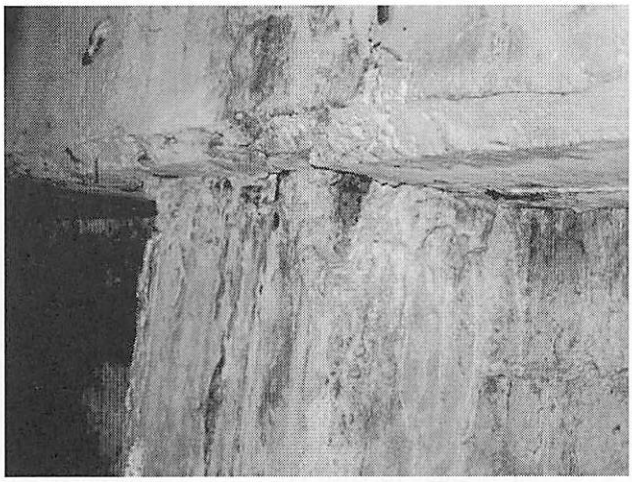


Figure B172: Honeycombs at the connection between column and beam

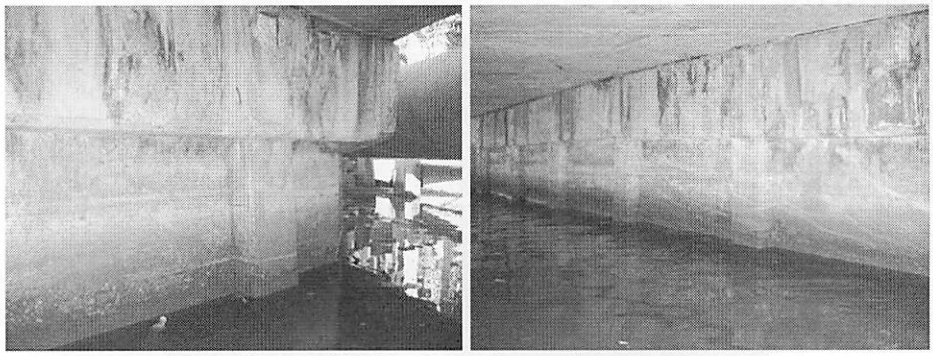


Figure B173: Overview of cap beam

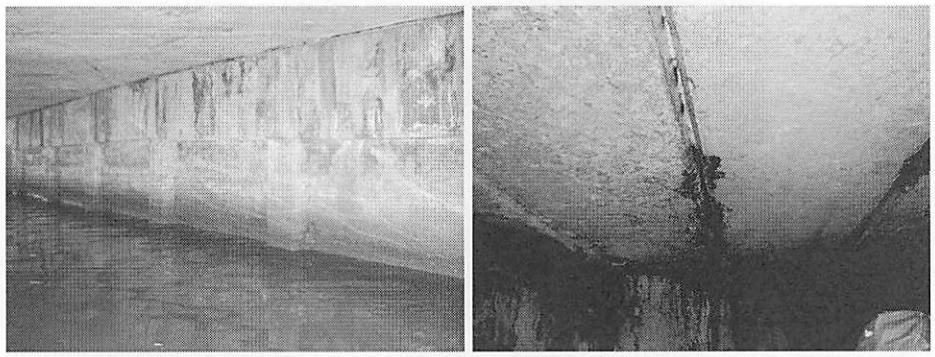
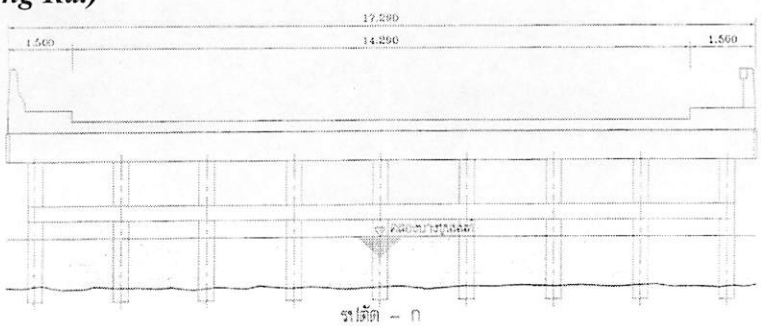


Figure B174: Slab in good condition with a little water leakage trace.

53. Bang Khun Non Canal - Bang Khun Non Road (Heading to Charan Sanitwong Rd.)



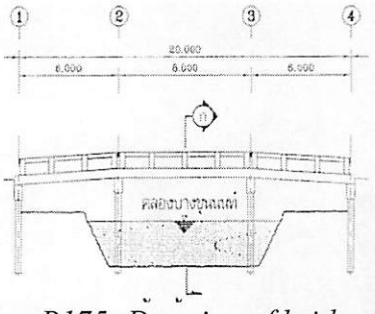


Figure B175: Drawing of bridge # 53

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Honeycombs
Beam	:	Spalling, Corrosion, Change of Surface Color
Slab	:	Spalling, Change of Surface Color

Deterioration Level: 3

Note : Guard rail is severely damaged

Figure B176: Spalling and corrosion

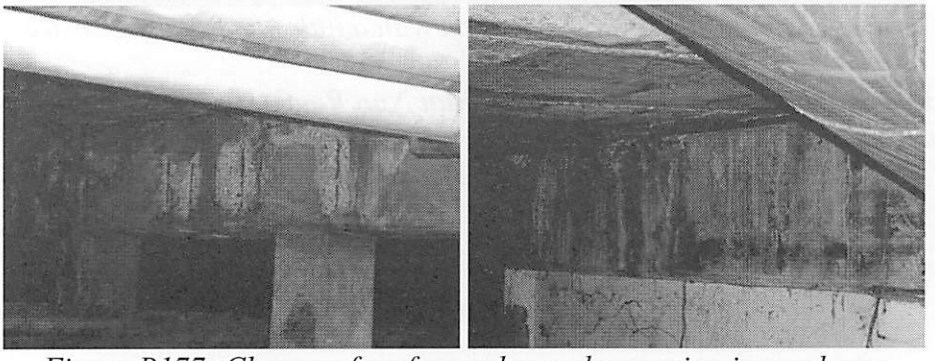


Figure B177: Change of surface color and corrosion in cap beam

54. Racha Montri Canal – Phattha Nakan Road (Heading to Ratcha Preuk Rd.)

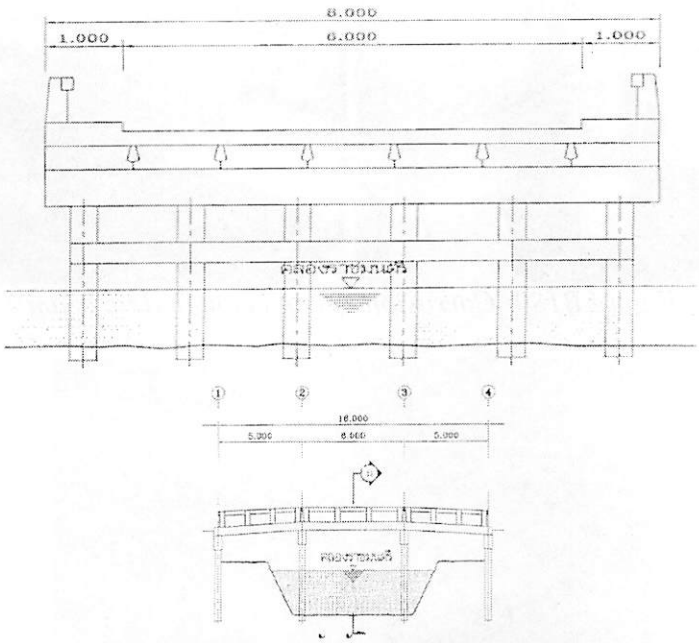


Figure B178: Drawing of bridge # 54

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Change of Surface Color, Inclining Column
Beam	:	Spalling, Corrosion, Change of Surface Color, Water Leakage
Slab	:	Corrosion, Cracks, Change of Surface Color

Deterioration Level: 4

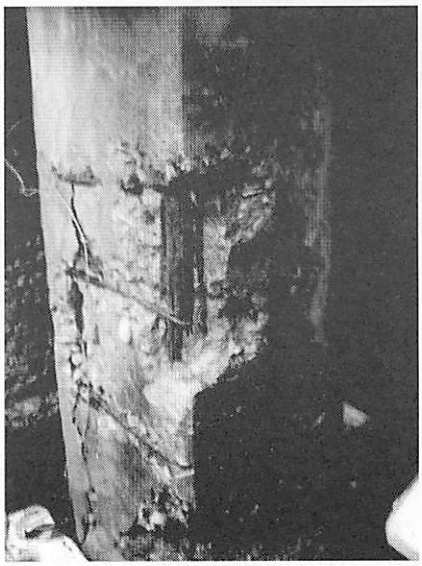


Figure B179: Severely corroded column

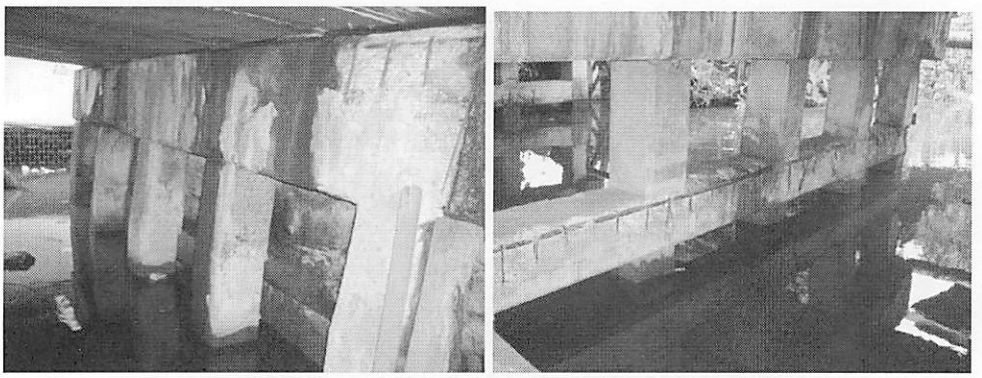


Figure B180: Corrosion in cap beam and tie beam

Figure B181: Stain in slab

55. Bang Ra Nae Canal - Phattha Nakan Road (Heading to Ratcha Preuk Rd.)

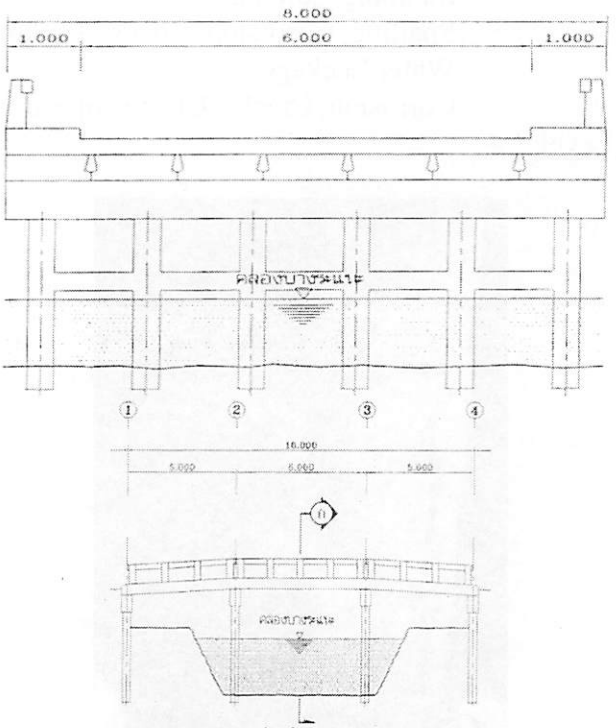


Figure B182: Drawing of bridge # 55

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion
Beam	:	Spalling, Corrosion, Change of Surface Color
Slab	:	Spalling, Corrosion

Deterioration Level: 3

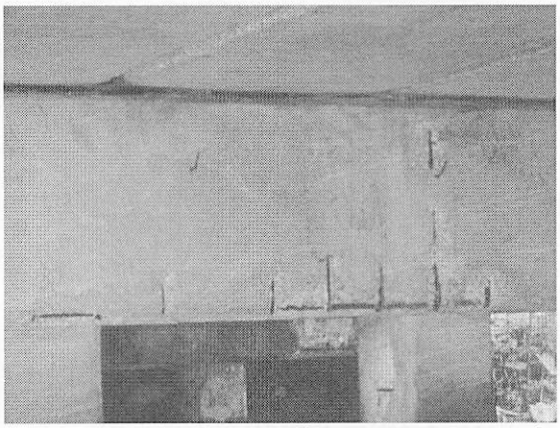


Figure B183: Spalling and corrosion in cap beam

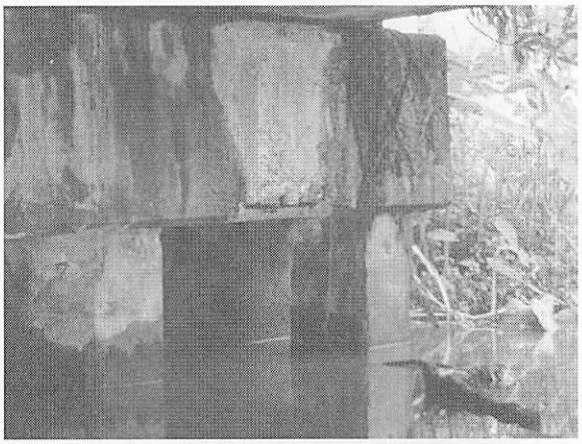


Figure B184: Water leakage accelerating deterioration of cap beam

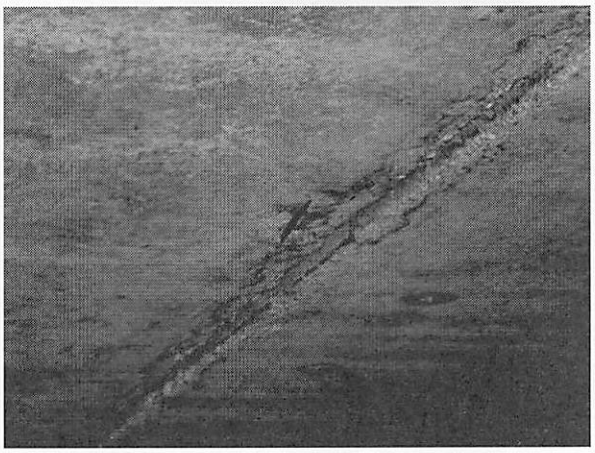


Figure B185: Small corrosion with minor spalling

56. Ta Paen Canal – Phattha Nakan Road (Heading to Ratcha Preuk Rd.)

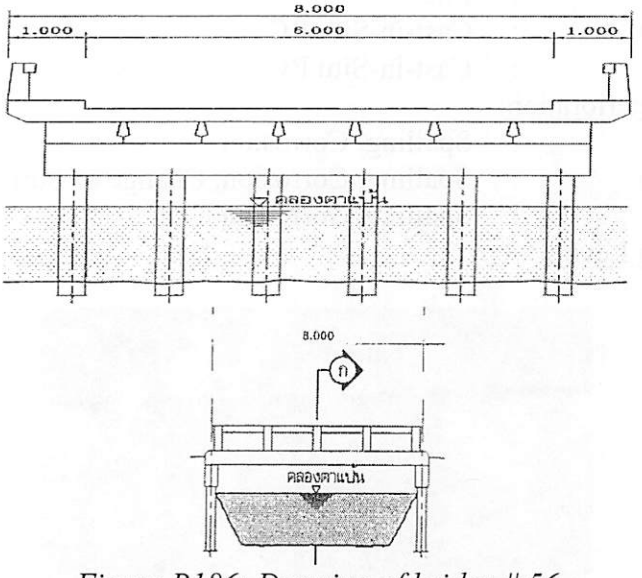


Figure B186: Drawing of bridge # 56

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Change of Surface Color
Beam	:	Spalling, Corrosion, Change of Surface Color, Water Leakage
Slab	:	Change of Surface Color, Water Leakage

Deterioration Level: 4

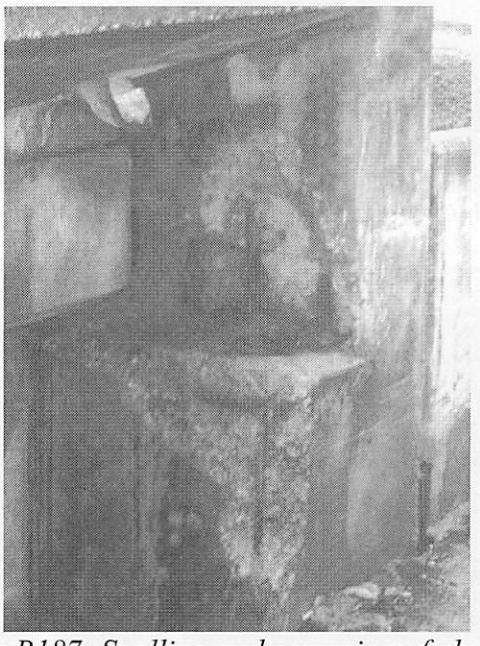


Figure B187: Spalling and corrosion of abutment

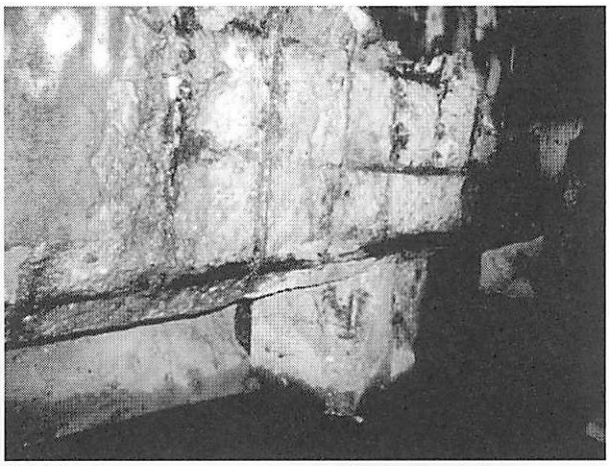


Figure B188: Severe corrosion inducing wide area of spalling

Figure B189: Leakage and leaching

57. Ta Cham Canal – Phattha Nakan Road (Heading to Ratcha Preuk Rd.)

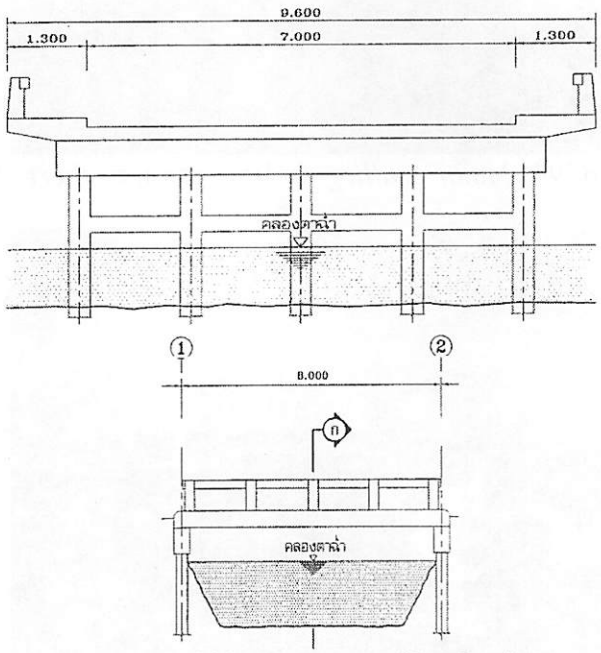


Figure B190: Drawing of bridge #57

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Water Leakage
Beam	:	Spalling, Corrosion, Change of Surface Color, Water Leakage
Slab	:	Spalling, Corrosion, Change of Surface Color, Water Leakage

Deterioration Level: 4

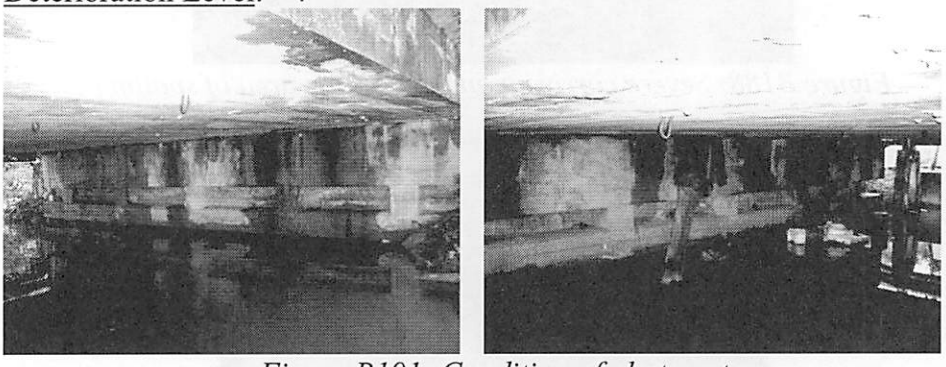


Figure B191: Condition of abutment

Figure B192: Minor spalling and corrosion in short column

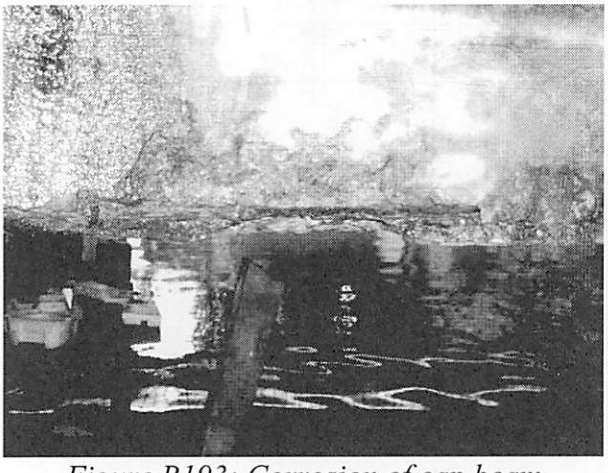


Figure B193: Corrosion of cap beam

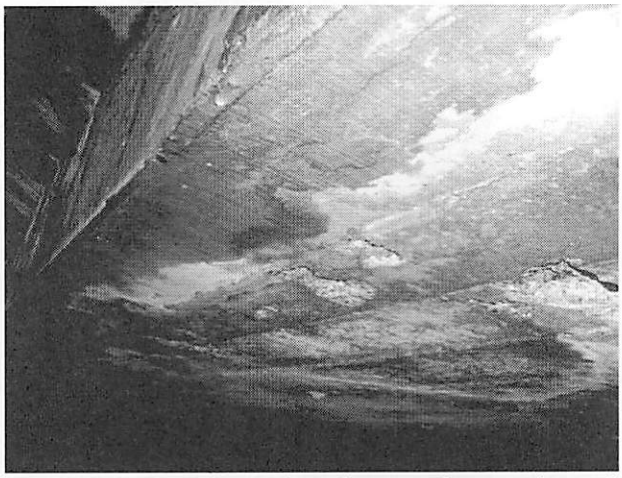


Figure B194: Leaching found on surface with spalling

58. No name canal – Phattha Nakan Road (Heading to Ratcha Preuk Rd.)

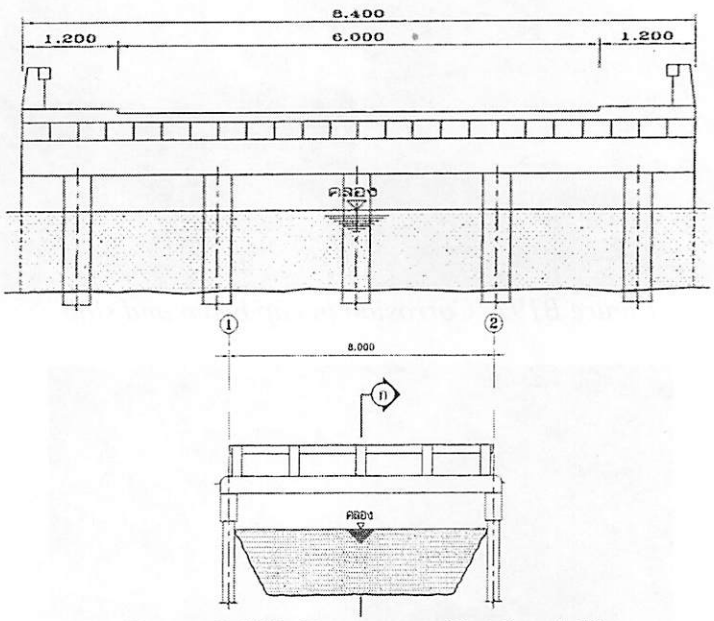


Figure B195: Drawing of bridge # 58

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Change of Surface Color
Beam	:	Spalling, Corrosion, Change of Surface Color
Slab	:	Spalling, Corrosion, Change of Surface Color

Deterioration Level: 4

Figure B196: Erosion and spalling of column

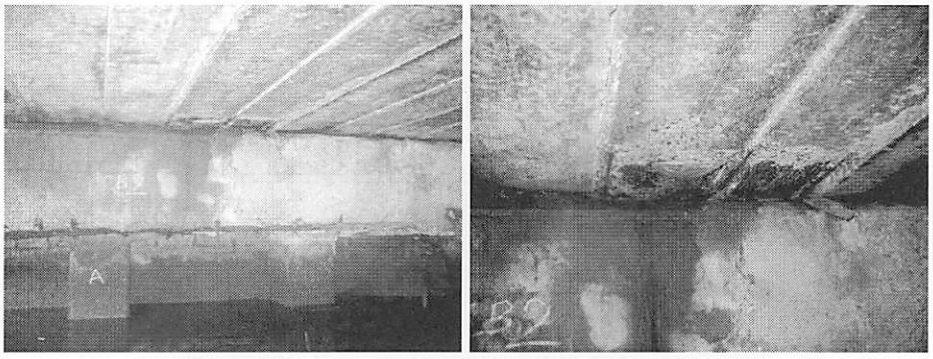


Figure B197: Corrosion in cap beam and slab

Figure B198: Corrosion condition

59. Bang Wa Canal – Phattha Nakan Road (Heading to Ratcha Preuk Rd.)

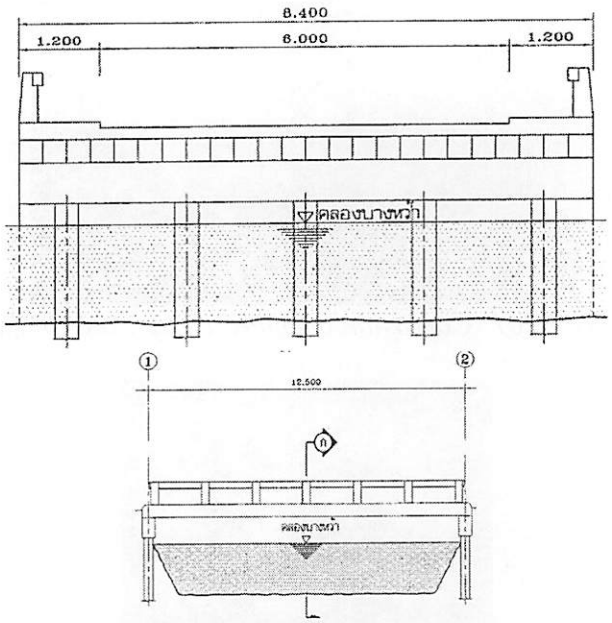


Figure B199: Drawing of bridge # 59

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Change of Surface Color
Beam	:	Spalling, Corrosion, Change of Surface Color, Water Leakage
Slab	:	Spalling, Corrosion, Change of Surface Color

Deterioration Level: 3

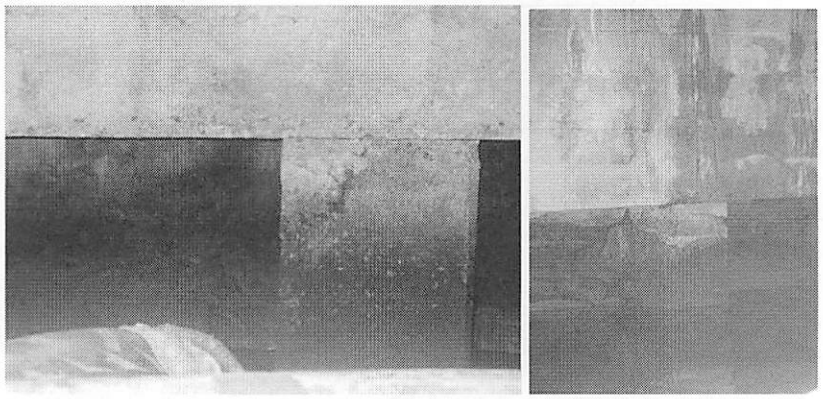


Figure B200:: Damages in connection between column and cap beam

Figure B201: Corrosion accelerated by water leakage

Figure B202: Corrosion taking place at the area subjected to water leakage

60. Wat Ang Kaew Canal – Phattha Nakan Road (Heading to Ratcha Preuk Rd.)

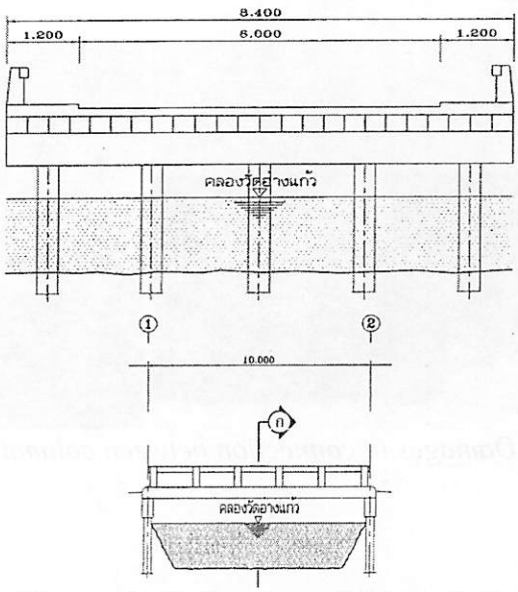


Figure B203: Drawing of bridge # 60

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Change of Surface Color, Erosion, Honeycombs
Beam	:	Spalling, Corrosion, Change of Surface Color, Honeycombs
Slab	:	Change of Surface Color

Deterioration Level: 3

Figure B204: Honeycombs in column indicating the construction quality

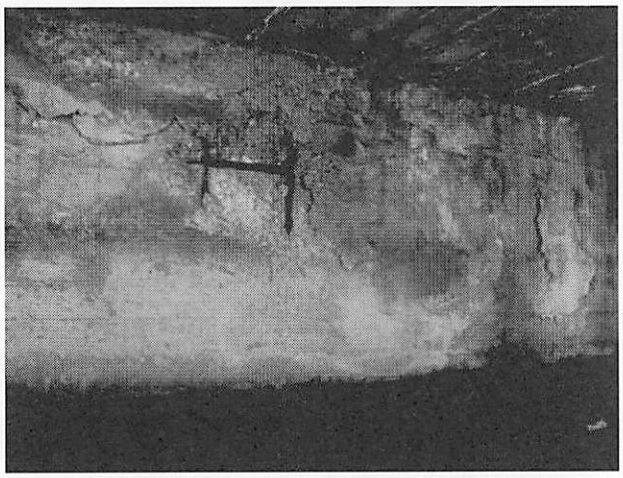


Figure B205: Spalling caused by corrosion

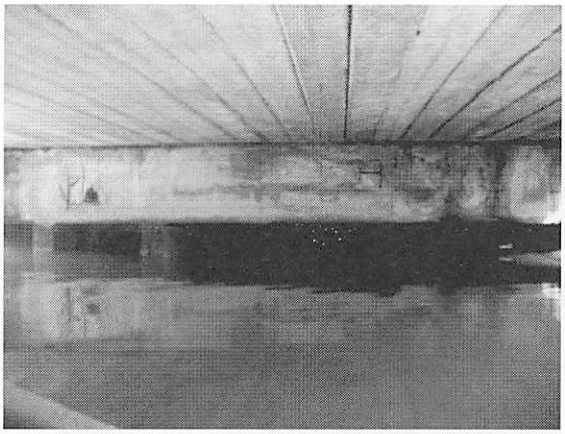


Figure B206: Slight color change of slab

61. Bang Chak Canal – Petcha Kasem Soi 88 (Heading to Petch Kasem Rd.)

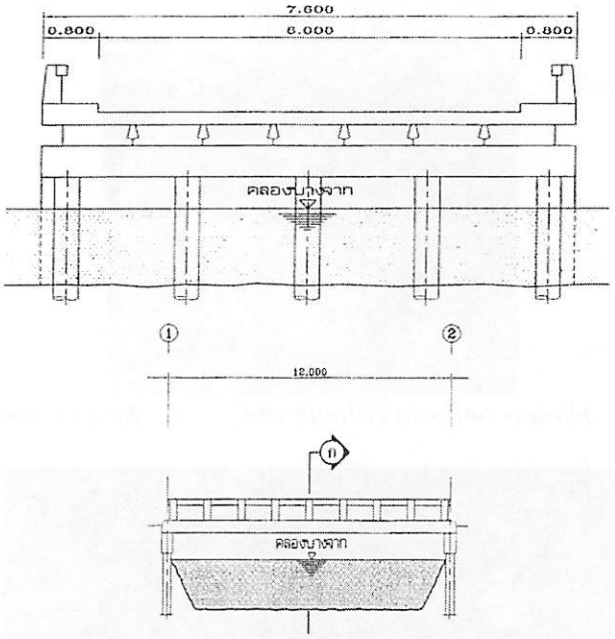


Figure B207: Drawing of bridge # 61

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Highly Loss of Sectional Area
Beam	:	Change of Surface Color
Slab	:	No Damage

Deterioration Level: 4

62. Lung Tui Canal – Racha Montri Road (Heading to Petch Kasem 58)

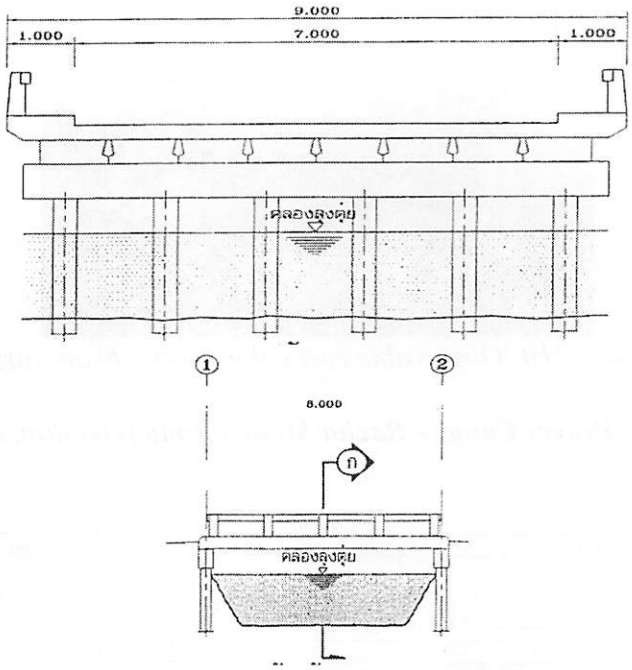


Figure B208: Drawing of bridge # 62

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Highly Loss of Sectional Area
Beam	:	Change of Surface Color
Slab	:	No Damage

Deterioration Level: 4

Note: Replacement of bearing is necessary.

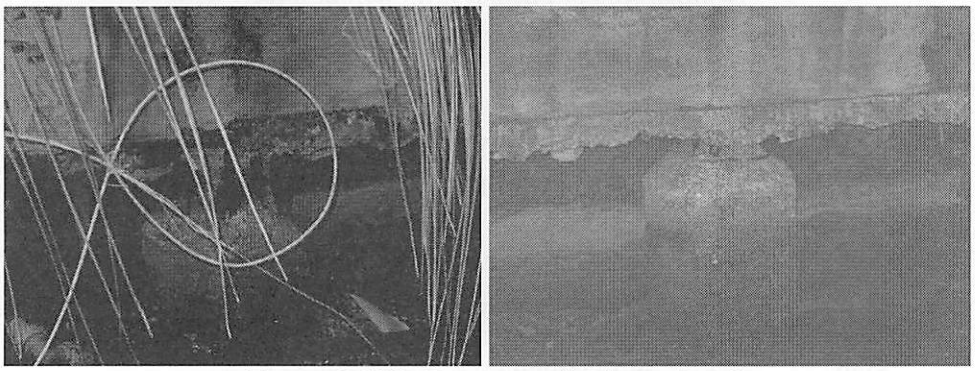


Figure B209: Damage of column heads

Figure B210: Observable rust color on cap beam surface

63. Satharana Prayot Canal – Racha Montri Road (Heading to Petch Kasem 58)

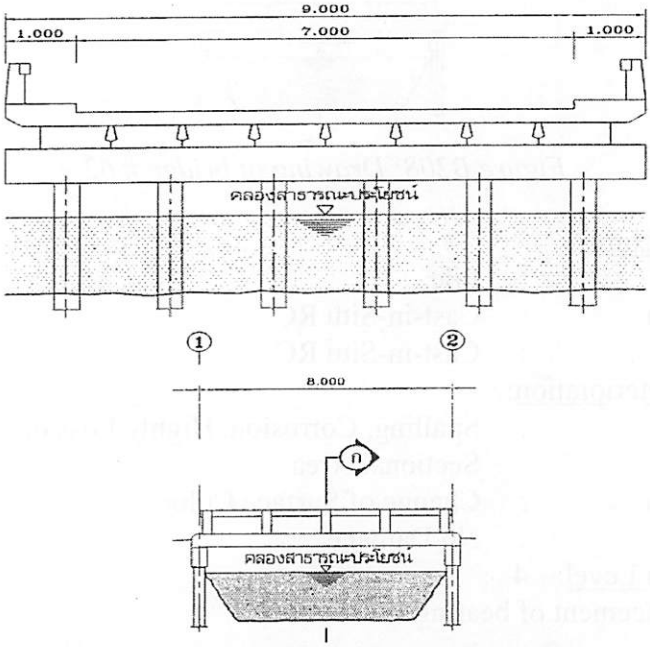


Figure B211: Drawing of bridge # 63

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Highly Loss of Sectional Area
Beam	:	Spalling, Corrosion
Slab	:	No Damage
Wall	:	Honeycombs, Corrosion

Deterioration Level: 4

Note: Replacement of bearing plate is required and severe crack is observable at the head of column

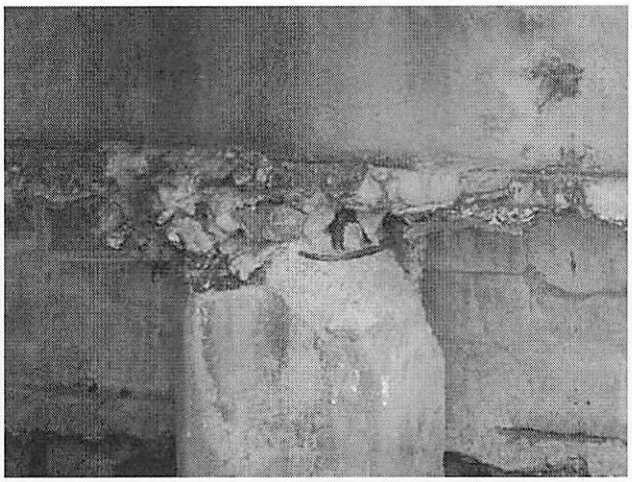


Figure B212: Severe damage which reduces the capacity of column

Figure B213: Condition of cap beams

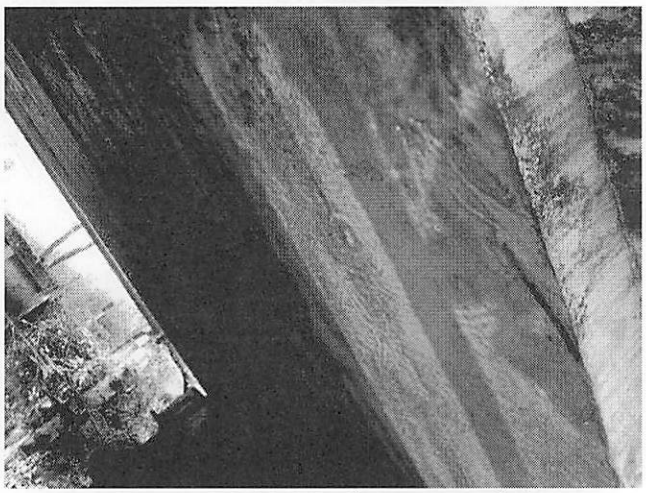


Figure B214: No damage in slab

64. Racha Montri Canal – Racha Montri Road (Heading to Petchakasem 58)

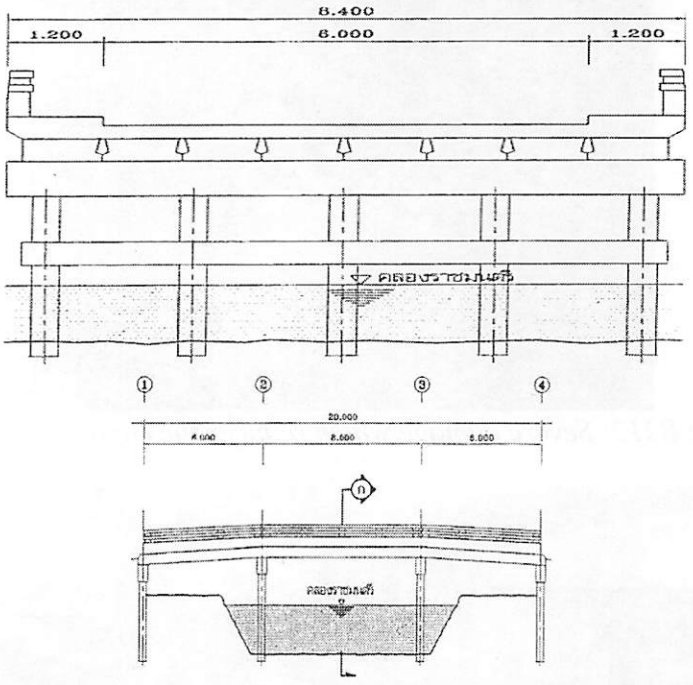


Figure B215: Drawing of bridge # 64

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion
Beam	:	Spalling, Corrosion, Honeycombs, Small Covering Depth
Slab	:	No Damage

Deterioration Level: 3

Figure B216: Corrosion of reinforcement in column

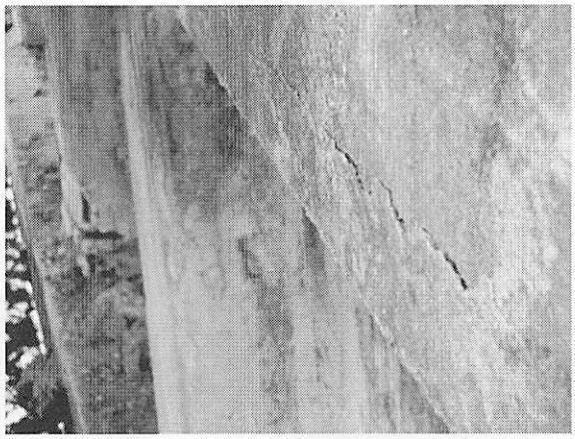


Figure B217: Observable corrosion cracks in cap beam

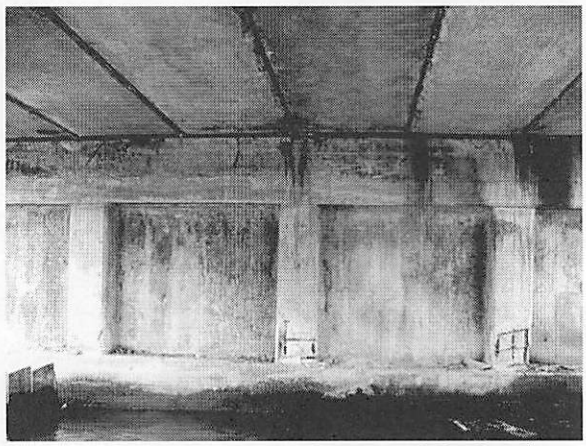


Figure B218: General view of the bridge

65. No Name Canal – Petcha Kasem Soi 58 (Heading to Petcha Kasem 58)

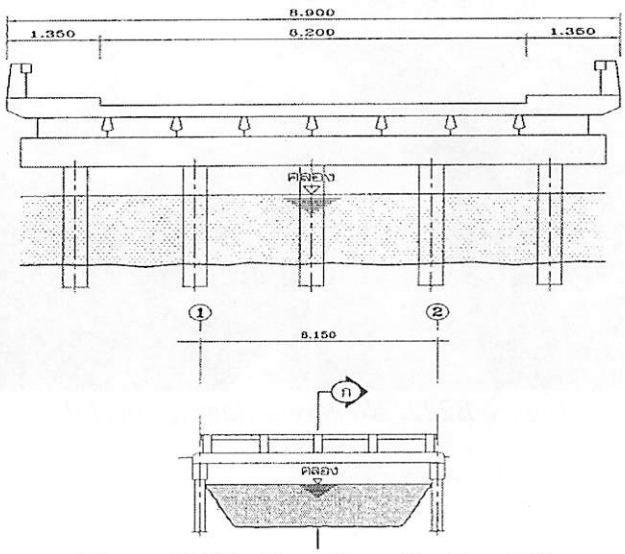


Figure B219: Drawing of bridge #65

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC

Slab : Cast-in-Situ RC

Observed Deterioration:

Pier : Corrosion, Honeycombs, Small Covering Depth, Erosion

Beam : Corrosion, Honeycombs, Small Covering Depth

Slab : No Damage

Deterioration Level: 4

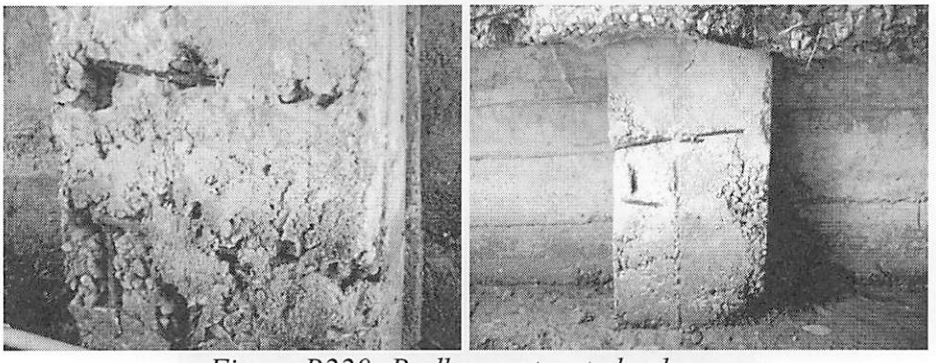


Figure B220: Badly constructed column

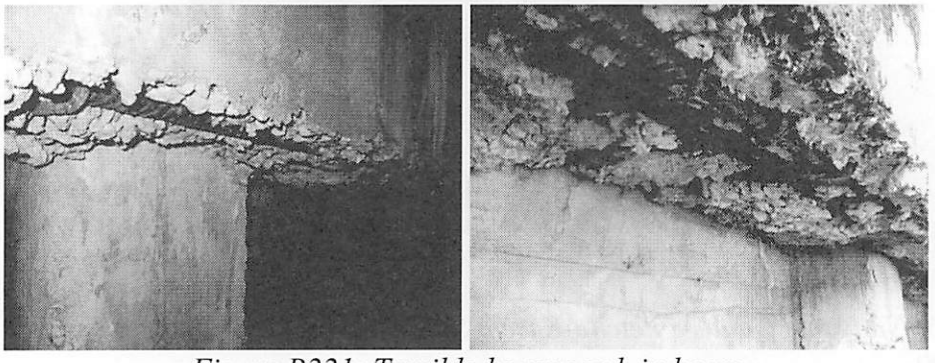


Figure B221: Terrible honeycomb in beam

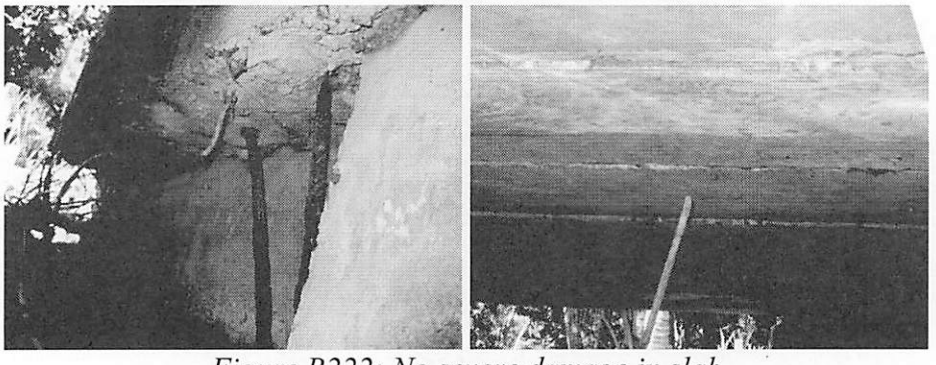


Figure B222: No severe damage in slab

66. Bang Duan Canal – Petcha Kasem Soi 58 (Heading to Petcha Kasem Rd.)

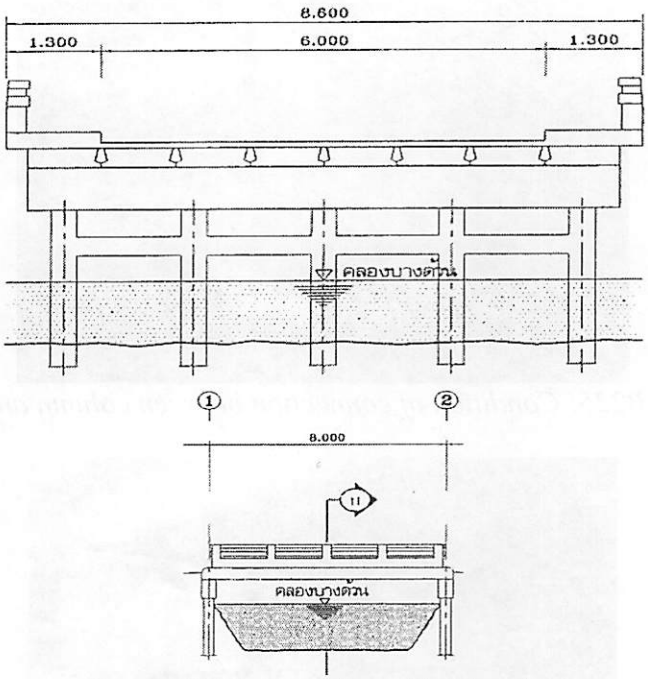


Figure B223: Drawing of bridge # 66

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Cracks, Honeycombs
Beam	:	Spalling, Corrosion, Change of Surface Color
Slab	:	No Damage

Deterioration Level: 3

Figure B224: Structural splitting crack in column

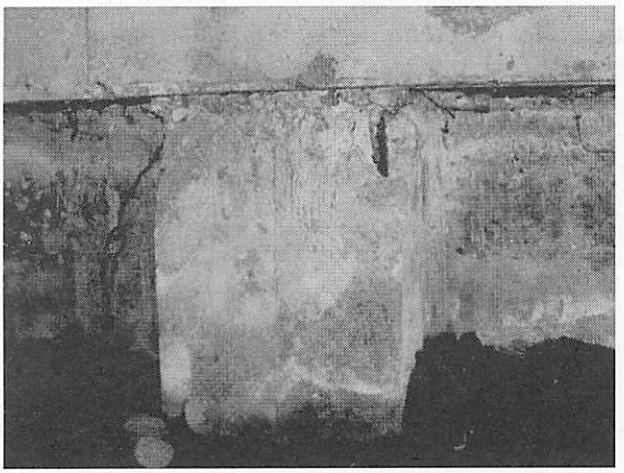


Figure B225: Condition of connection between column and beam

Figure B226: Water leakage and stain on cap beam

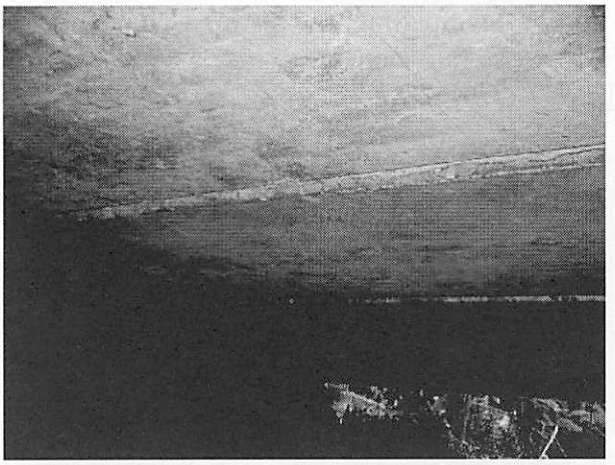


Figure B227: Slab in very good condition

67. Bang Duan Canal – Petcha Kasem Soi 58 (Heading to Petch Kasem Rd.)

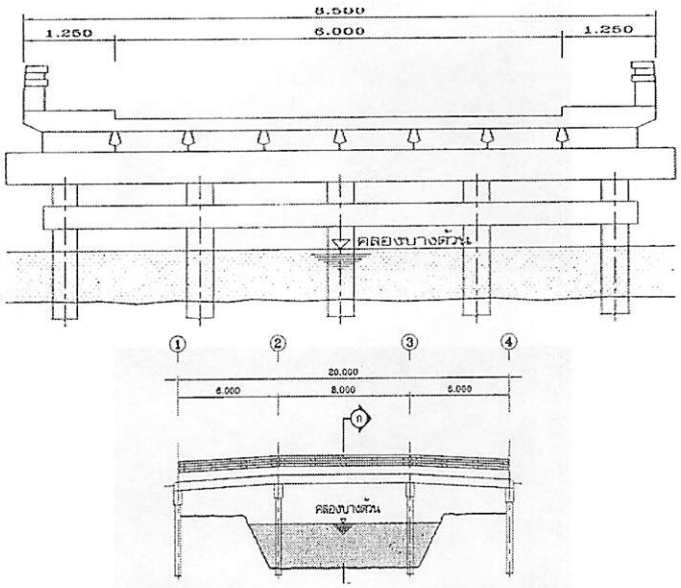


Figure B228: Drawing of bridge #67

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Change of Surface Color
Beam	:	Spalling, Corrosion, Change of Surface Color
Slab	:	Change of Surface Color

Deterioration Level: 3

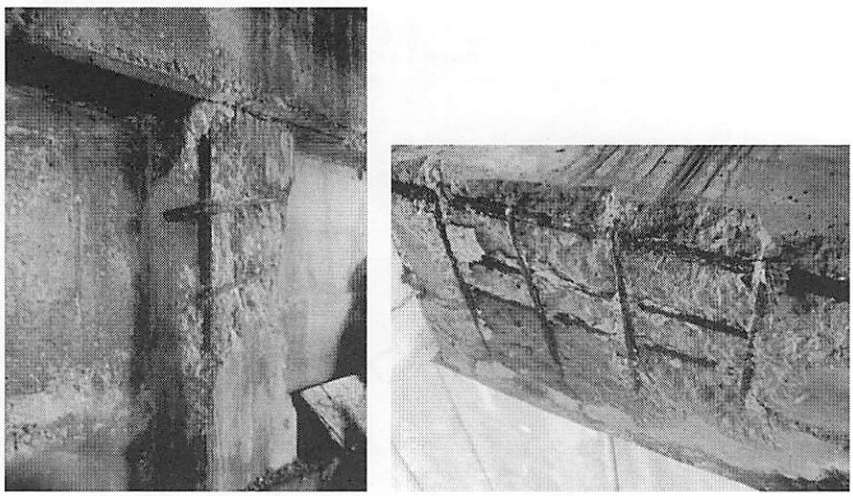


Figure B229: Intensive corrosion of column

Figure B230: Substantial loss of cross section of cap beam

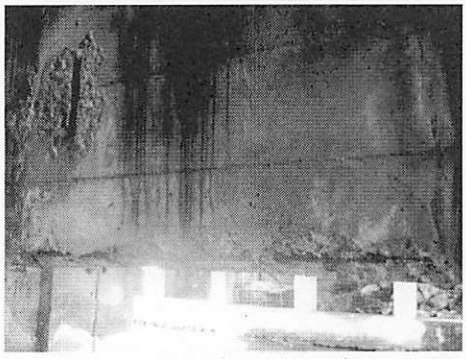


Figure B231: Extensively distributed corrosion in a wall

68. Lam Ma Dong Canal – Petch Kasem Soi 58 (Heading to Petch Kasem Rd.)

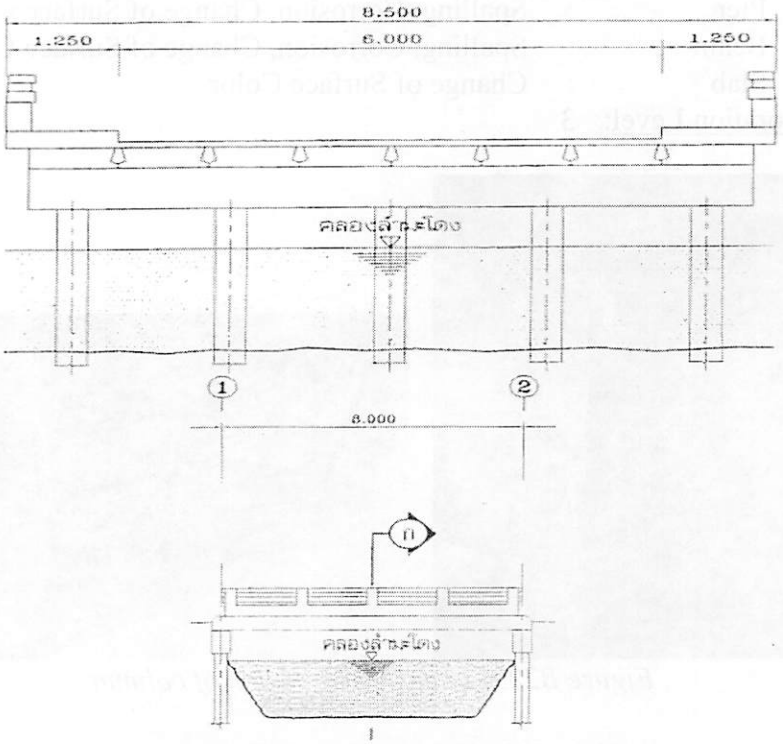


Figure B232: Drawing of bridge #68

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC

Slab : Cast-in-Situ RC

Observed Deterioration:

Pier : Honeycombs, Erosion, Small Covering Depth

Beam : Honeycombs, Erosion

Slab : Spalling

Deterioration Level: 3

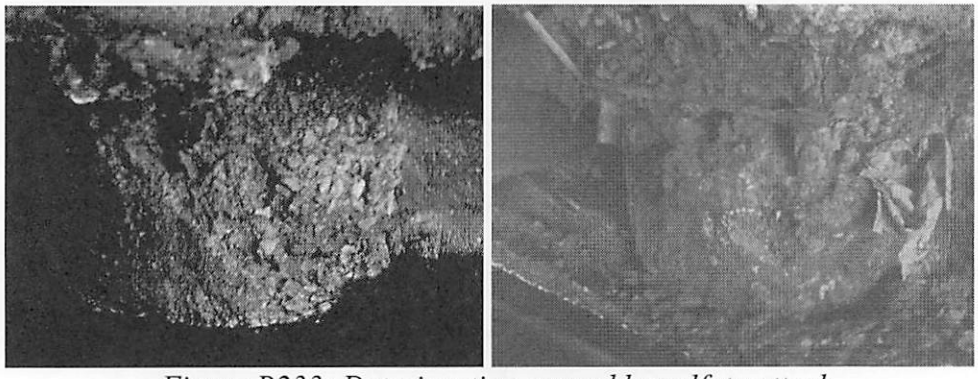


Figure B233: Deterioration caused by sulfate attack

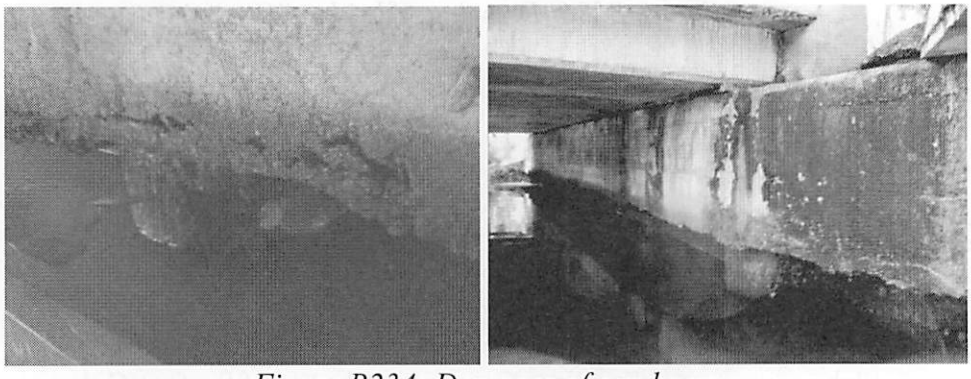


Figure B234: Damages of cap beam

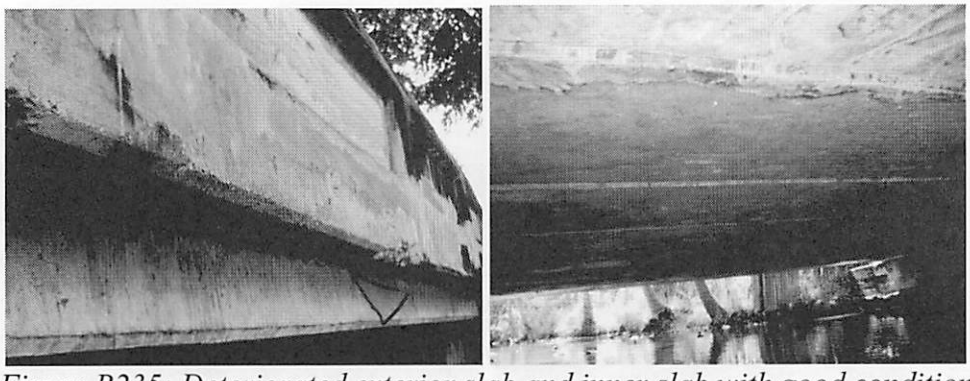


Figure B235: Deteriorated exterior slab and inner slab with good condition

69. Bang Chak Canal – Petcha Kasem Soi 48 (Heading to Petch Kasem 48)

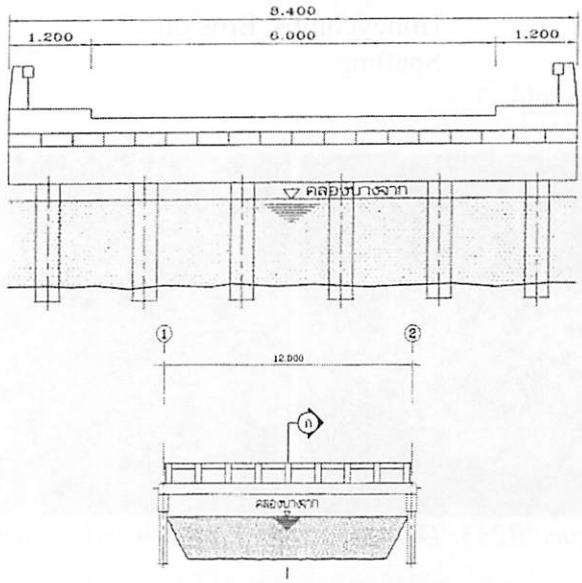


Figure B236: Drawing of bridge #69

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Spalling, Corrosion, Honeycombs, Loss of Sectional Area
Beam	:	Spalling, Corrosion
Slab	:	Spalling, Corrosion, Change of Surface Color

Deterioration Level: 4

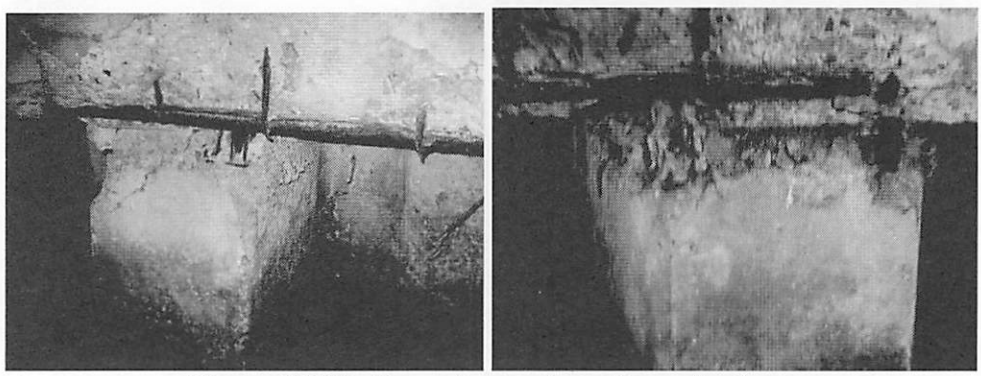


Figure B237: Corrosion and spalling of column

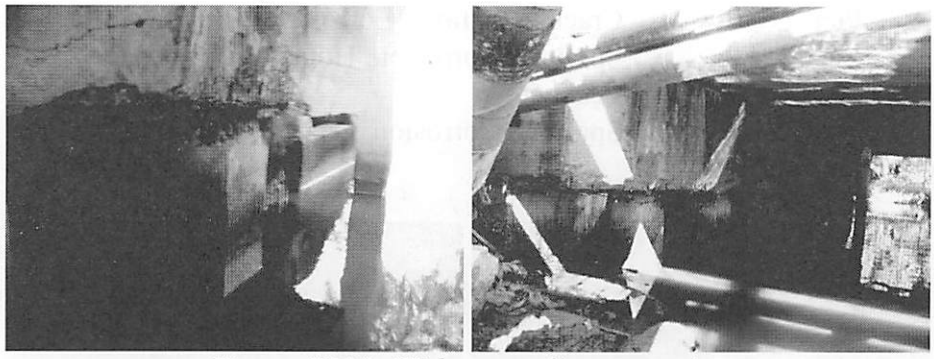


Figure B238: Wide-spreading corrosion

Figure B239: Water leakage and localized corrosion

70. Maha Sorn Canal – Liab Khlong Phasi Charoen Rd. (Heading to Intra Paj 13 Intersection)

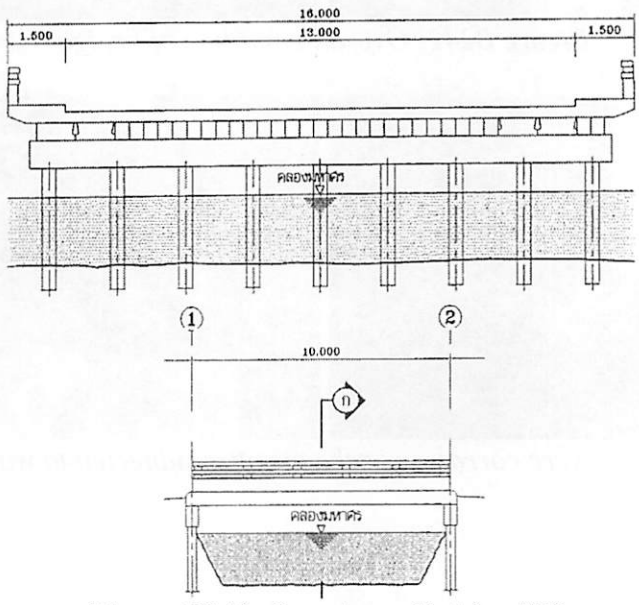


Figure B240: Drawing of bridge #70

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Cracks, Spalling, Corrosion
Beam	:	Spalling, Corrosion, Honeycombs, Water Leakage
Slab	:	Spalling, Corrosion, Change of Surface Color

Deterioration Level: 3

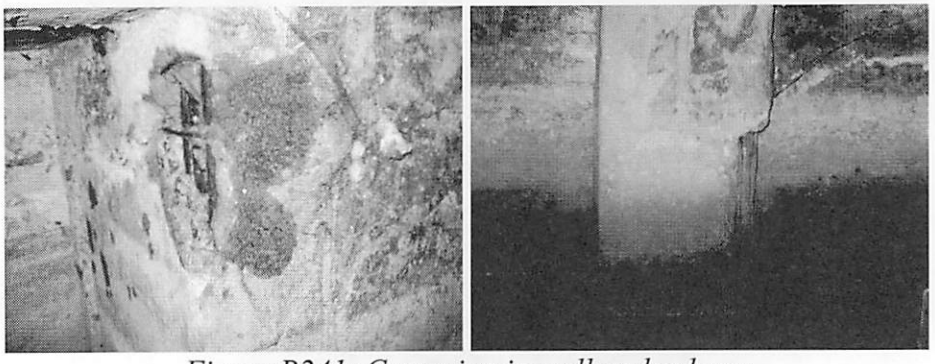


Figure B241: Corrosion in wall and column

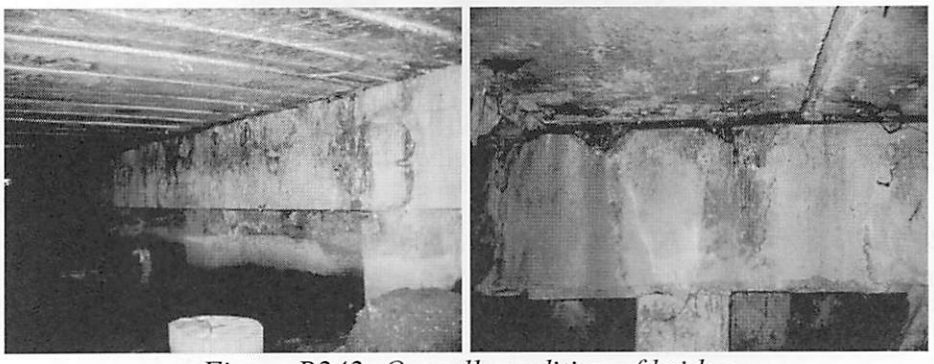


Figure B242: Overall condition of bridge

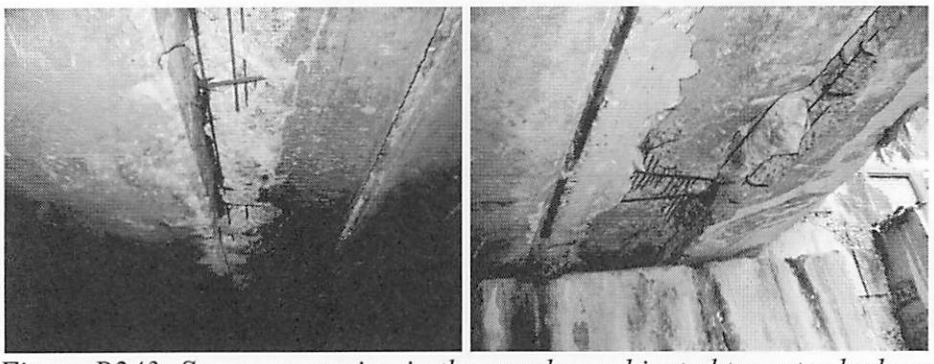


Figure B243: Severe corrosion in the member subjected to water leakage

71. No Name Canal – Liab Khlong Phasi Charoen Rd. (Heading to Petch Kasem 63)

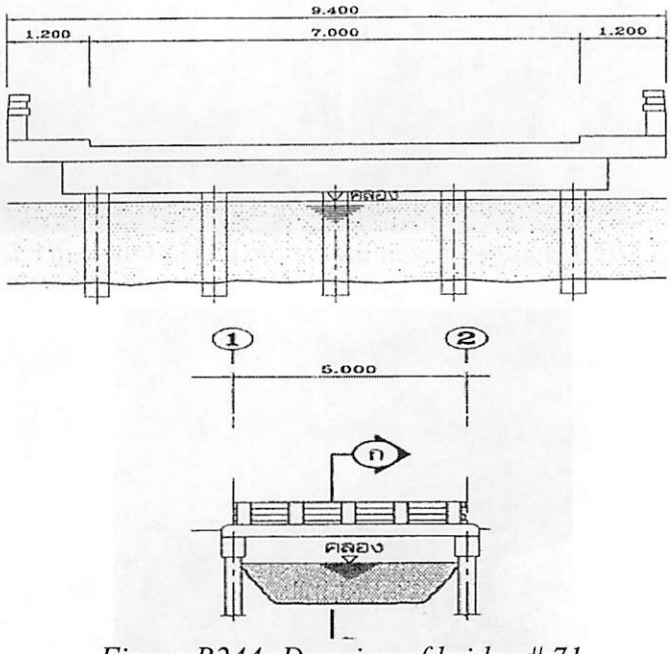


Figure B244: Drawing of bridge # 71

Type of Structure:

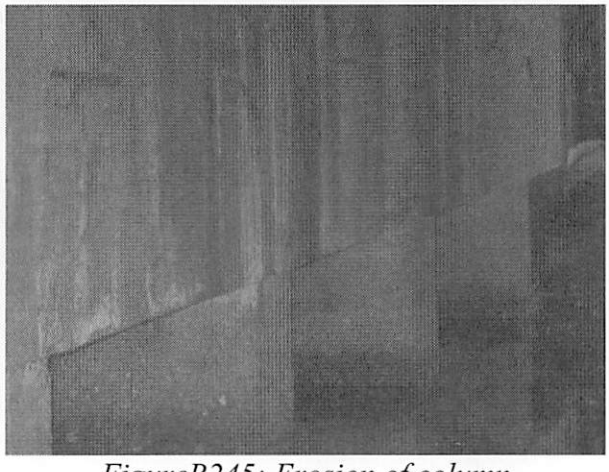
Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Erosion
Beam	:	Spalling, Corrosion, Split Crack by Concentrated Load
Slab	:	Edge Crack caused by Concentrated Load

Deterioration Level: 2

Note: Need bearing pad addition and replacement



FigureB245: Erosion of column

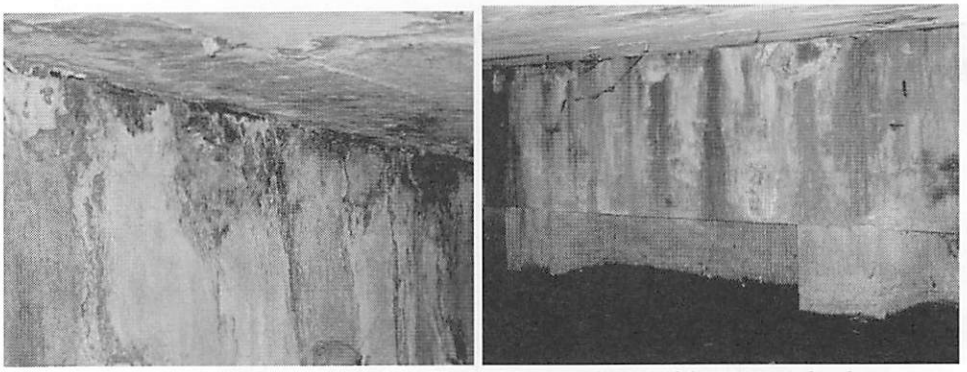


Figure B246: Damage of wall and beam caused by water leakage

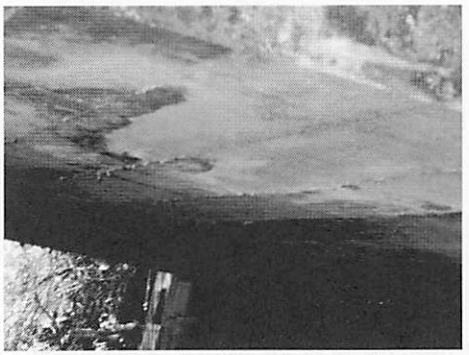


Figure B247: Condition of slab

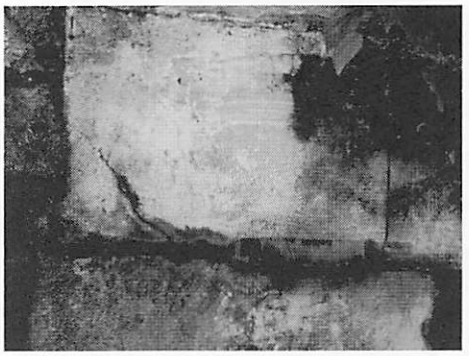
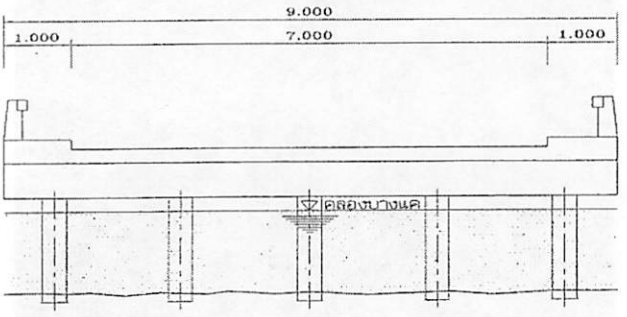


Figure B248: Crack by bad distribution of load

72. Bang Khae Canal – Petch Kasem Soi 63 (Heading to Petch Kasem Rd)



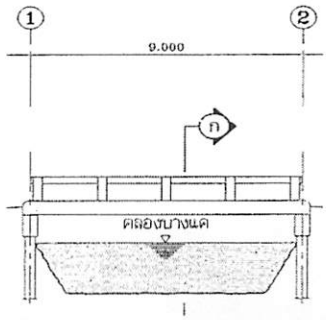


Figure B249: Drawing of bridge #247

Type of Structure:

Pier	:	Pile
Beam	:	Cast-in-Situ RC
Slab	:	Cast-in-Situ RC

Observed Deterioration:

Pier	:	Cracks, Spalling, Corrosion, Loss of Sectional Area
Beam	:	Spalling, Corrosion, Honeycombs
Slab	:	Spalling, Corrosion

Deterioration Level: 4

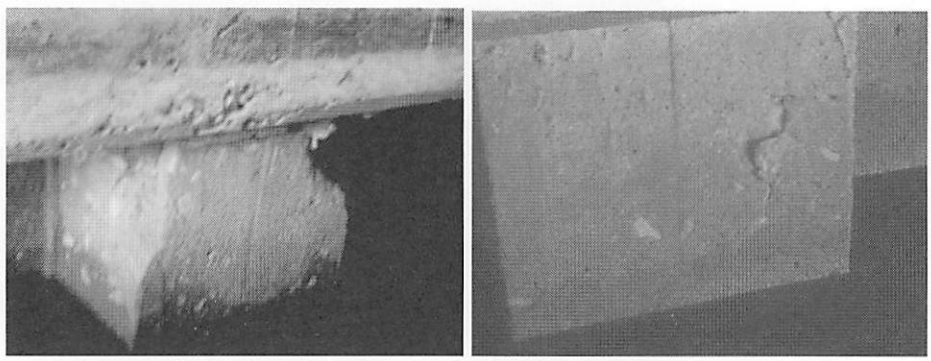


Figure B250: Damage of columns

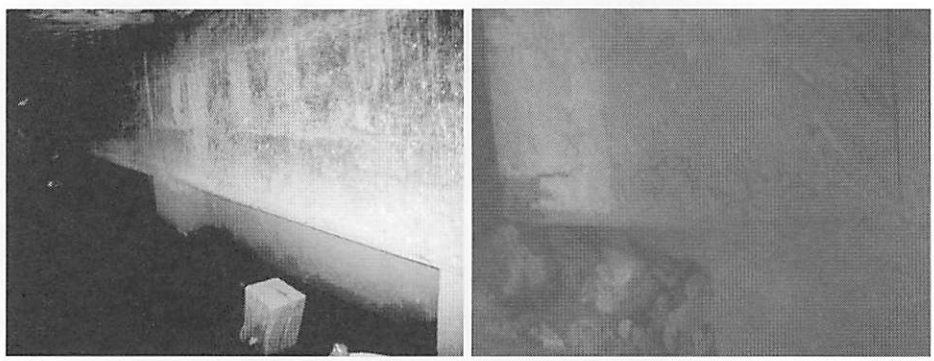


Figure B251: Condition of cap beam

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