2.7 Scoping

2.7.1 Basic Concept of Scoping

Scoping is defined as a process of identification of the critical environmental impacts out of the possible environmental impacts of a development project. Through the scoping process, the priority fields or items of an environmental impact assessment are also identified. Further, it recommends that scoping should be carried out through discussions with the government agencies. These discussions are to be based on discussion items prepared in advance, and by taking into account the aforementioned cross-sectional judgement provisions.

With the above definition and the methods used by various agencies, the guidelines provide material for conducting adequate scoping. The guidelines would enable even those who are not IEE and Pre-EIA specialists to understand the overall picture of the development project to conduct the sufficient scoping work during the short-term preparatory study period.

2.7.2 Scoping Methods

(1) Outline

There are several technical methods for environmental impact assessment and its scoping. Each of them is selected in accordance with the project type, the project planning level, the features of the environmental conditions, etc. The most common methods are the checklist method and the matrix method.

Identification of the critical environmental impacts out of the possible impacts of a development project shall be required by the definition of scoping. It is necessary to include all environmental items which can be predicted to arise along with implementation of the project. To accomplish this, the checklist method seems to be the easiest to understand and the most useful.

Based on the above consideration, the checklist method is proposed for scoping in the guidelines.

To clarify important fields and items among those listed on the checklist, it is necessary to understand the causal relationships between the environmental items and the project related activities during the construction and the operation periods. Thus, to make it easier to understand scoping, the guidelines show typical causal relationships between development activities and environmental items by using the matrix as well as the checklist.

(2) Scoping of Road and Bridge Projects

The checklist for scoping of road projects is shown in Table 2.4. The matrix for understanding the causal relationship between the development activities and the environmental items is shown in Table 2.6 of the following chapter.

To use the checklist for scoping, the following conditions and procedures should be taken into account:

a) Application conditions

- Periods covered by scoping: Scoping should cover both the construction and operation periods.
- Spatial extent of scoping: Scoping should cover the project site and its vicinities.
- Types of Environmental Impacts: Environmental impacts subject to scoping are those having negative impacts on the existing environment.

b) Evaluation method of important fields and items

The evaluation of each item should be rated according to the following categories:
A: (serious impact is expected):
B: (some impact is expected):
C: (extent of impact is unknown but further examination is required because it might become clear as the study progresses):
D: (no impact is foreseeable and IEE/Pre-EIA is not required).

Important fields and items for IEE/Pre-EIA/EIA should be identified with reference to "possible environmental impacts," "useful factors for evaluation," "measures," and "related subjects for study" as described in 2.5.1, 2.5.2 and 2.5.3 at previous section.

Table 2.4 Format for scoping

No.	Environmental component	Identification of activities	IEE evaluation	Remarks (Reason)
Socio economic Environment				
1	Land and Property	Land aquisition Resettlement		
2	Economic	Economic activities		
		Employment		
3	Traffic and Public facilities	Traffic Public facilities		
4 5	Communities Amenity	Disintegration of communities Amenities		
6	Historical and Cultural	Historical assets Cultural properties		
7	Vested rights	Water rights and rights of common		
8	Waste	Waste		
9	Hazards	Risk and damage		
Natural Environment				
10	Land	Topographic feature / river bank and bed		
		Geological condition		
		Land use		
		Soil erosion		
11	Surface water	Hydrological feature		
		Water use		
		Water quality		
		Floating debris		
		Flood affection		
12	Species and their population, habitat	Terrestrial vegetation / flora		
		Terrestrial wildlife / fauna		
		Aquatic flora		
		Aquatic fish fauna		
13	Aesthetics	Landscape		
Environmental Pollution				
15	Atmosphere	Air pollution		
16	Water	Water pollution		
17	Noise/vibration	Noise and vibration		
Overall evaluation:		Is Preliminary EIA necessary for the project implementation?	Need of Pre-EIA?	

c) Overall evaluation

The evaluation results of each environmental item and the reasons for the evaluation should be clearly described on the checklist. The items evaluated as A, B, or C should be examined based on the screening concept to determine whether or not IEE/Pre-EIA/EIA is required, and the policies for further study of those items should be outlined. If it is possible to alleviate or avoid some environmental impacts by taking adequate measures, the contents should be described.

If, as the result of the evaluation, there are items which are evaluated as "C" or higher, some studies should be conducted for these items.

CHAPTER 3 PRELIMINARY ENVIRONMENTAL IMPACT ASSESSMENT

3.1 General

The objectives of Preliminary environmental Impact Assessment (Pre-EIA) are as follows.

a) To examine and select from the project options available,
b) To identify and incorporate into the project plan appropriate abatement and mitigating measures,
c) To identify the significant residual environmental impacts

Pre-EIA should normally be initiated at an early stage of project planning. Standard Procedural Steps are provided and the assessment might be conducted "in house", or by a consultant. The Assessment tool is a matrix. Some form of public participation is mandatory. Environmental data collection may be necessary and close liaison between the assessor and relevant environment related agencies is encouraged. The results of Pre-EIA are reported formally for examination and approval by the project approving authority.

Pre-EIA requires resources that are a small proportion of the man-hours; money, skills and equipment committed to a feasibility study and the assessment should be completed within the time frame of that study.

3.2 Time Frame

At the stage of "Project Description", well before planning studies are initiated, (it is possible to determine whether a project should undergo Pre-EIA. The nature of the project and its general location are the only information required making that decision. This "screening" of projects, prior to Pre-EIA, can be completed in a matter of hours) a project should be screened by checking with the Schedule of Project Activities to determine whether the project should undergo Pre-EIA.

Pre-EIA is not intended to be a time consuming procedure. It should however be spread over the duration of a project options (feasibility) study so that as the project concept develops into an outline plan, the environmental as well as the economic and technical assessment of the project can be reviewed.

3.3 Manpower

Determining whether a project should undergo Pre-EIA is rather desk exercise. It is likely that the responsible personnel of the project development body preparing project identification report, minute or file note, would at the same time make that decision and include in his project identification a brief comment as to whether or not the project is a Prescribed Activity.

Within the project planning team for a large road and bridge project, the responsible personnel individual should be given the responsibility for coordinating the Pre-EIA. He need not be an environmental expert but he should have a responsible attitude towards the environment and have an interest in environmental matters. He should have direct access to the project director and should sit on the same planning coordination committees as the technical and economic planning coordinators.

In smaller projects one individual might fulfill all the functions of technical, economic and environmental planner.

3.4 Projects Most in Need of Environmental Assessment

(1) Identification of anticipated effects

Projects, which are most in need of the environmental assessment, can be identified on the basis of a number of criteria, which aim at ascertaining whether the anticipated direct or indirect effects of a project on the environment are likely to be significant.

(2) Major effects to be considered

When judging whether a specific project may have a major effect on the environment, it is necessary to take into account, among other things, the ecological conditions in the area where it is planned to locate the project. In-depth environmental assessment is always needed in certain very fragile environments (e.g. wetlands, mangrove swamps, coral reefs, tropical forests, and semi-arid areas). When carrying out environmental assessment issues, which should be considered, include effects on:

a) Soils and soil conservation (erosion, salination etc.),
b) Areas subject to desertification,
c) Tropical forests and vegetation cover,
d) Water sources,
e) Habitats of value to protection and conservation and/or sustainable use of fish and wildlife resources,
f) Areas of unique interest (historical, archaeological, cultural, aesthetic, scientific),
g) Areas of concentrations of population or industrial activities where further industrial development or urban expansion could create significant environmental problems (Especially

regarding air and water quality),

h) Areas of particular social interest to specific vulnerable population groups (e.g. nomadic people or other people with traditional lifestyles).

(3) Projects most in need of environmental assessment fall under the following headings:

Projects most in need of environmental assessment fall under the following headings for roads and bridges as infrastructure work.

The above list of projects shown 3.4 in this section is not in any order of importance, and is not meant to imply that any particular project type is necessarily more in need of environmental assessment than another. In addition, the list is not meant to be exhaustive as there may be projects not mentioned above which may still have-significant effects on the environment in certain areas.

Although the presence of a project on the above list does not imply, that such a project will necessarily have significant adverse effects on the environment, but some projects indeed have positive environmental effects. Experience has shown that there is often a need to take particular measures to eliminate or mitigate the adverse environmental consequences of such projects. Whether a project should be subject to in-depth environmental assessment will therefore depend on an analysis of all the facts of the specific case.

3.5 Approach in Establishing an Environmental Assessment Process

Whether a new process for assessing the environmental impacts of development activities is created or existing procedures are adapted to such a process. It is suggested that environmental assessment be integrated at an early stage of project planning reflected in the implementation of the activity and followed up by monitoring and post-audit evaluation.

The following elements of such a process have been found useful:

a) An initial screening process should be undertaken to determine whether or not a full EIA is required.

b) An EIA on a project should begin at the pre-feasibility or project proposal stage and be integrated with cost-benefit and engineering feasibility studies.

c) The content of the assessment should be determined by a procedure designed to identify reasonable project alternatives and the most significant environmental impacts associated with them. The reason for doing so is to ensure that the ensuing assessment is carried out in the most timely, and cost-effective manner by addressing only the most important issues necessary for making a decision.

The procedure should be implemented preferably with a group of individuals responsible for the project, coming together to discuss the issues and determine those to be addressed in the assessment.

d) After this, terms of reference should be drawn up for the assessment itself. It is depending on the size, nature and location of the project. The assessment can range from a one to two page analysis, which is based on existing information and carried out by a single individual to a comprehensive EIA that is based on extensive field surveys and data gathering and carried out by an interdisciplinary team.

e) An assessment should not only point out the possible environmental consequences of a particular activity but also suggest mitigating measures or alternative designs for limiting negative environmental impacts should the project be implemented. In addition, attention should be given to the creation of appropriate institutional mechanisms to ensure that mitigation measures are carried out.

3.6 Preliminary Environmental Impact Assessment Methodology

3.6.1 Preliminary Environmental Impact Assessment Matrix

For summerising IEE result if further examination will be required, an evaluation format for Pre-EIA shall be made with study plan and specific remarks on each objective effects. A format for pre-EIA is shown in Table 2.5. And a matrix of the project activity list for Pre-EIA is shown in Table 2.6 regarding on each scheduled activity. The matrix relates a list of project activities to components of the Socio-economic, natural environment and environmental pollution. The matrices have been prepared in consultation with development body and agencies concerned but can be modified to suit the requirements of a particular project. A general matrix is available for the Pre-EIA of projects not provided for specifically.

Project activities are listed on the horizontal axis of each matrix and are grouped according to the stages of project development in which they occur, namely:

(1) Pre-construction Stage
(2) Construction stage
(3) Operation and Maintenance Stage
(4) Consequent Projects

Activities of a Consequent Projects, which may result from the project, is also given. Each project activity is shown in the previous section 2.5 of chapter 2 and the relevant factors to be considered for each are also given.

On the vertical axis of each matrix environment components of the Socio-economic, natural, and environmental pollution are listed, and these are further subdivided into environmental components. Each characteristic and component is shown in the section 2.5 of the chapter 2.

The purpose of the matrix is to help the project planner to:

(1) Identify specific sources of potential environmental impact,

(2) Provide a means of comparing the predicted environmental impacts of the various project options available,

(3) Communicate in graphic form,

(a) Potentially significant adverse environmental impact for which a design solution has been identified
(b) Adverse environmental impact that is potentially significant but about which insufficient information has been obtained to make a reliable prediction
(c) Residual and significant adverse environmental impacts
(d) Significant environmental enhancement.

Table 2.5 Format for Pre-EIA evaluation

Project no. and Name: Location: Region Province

No.	Environmental component	Identification of activities	Pre-EIA evaluation	Study plan and Remarks (Reason)
Socio economic Environment				
1	Land and Property	Land aquisition Resettlement		
2	Economic	Economic activities		
		Employment		
3	Traffic and Public facilities	Traffic Public facilities		
4	Communities	Disintegration of communities		
5	Amenity	Amenities		
6	Historical and Cultural	Historical assets Cultural properties		
7	Vested rights	Water rights and rights of common		
8	Waste	Waste		
9	Hazards	Risk and damage		
Natural Environment				
10	Land	Topographic feature / river bank and bed		
		Geological condition		
		Land use		
		Soil erosion		
11	Surface water	Hydrological feature		
		Water use		
		Water quality		
		Floating debris		
		Flood affection		
12	Species and their population, habitat	Terrestrial vegetation / flora		
		Terrestrial wildlife / fauna		
		Aquatic flora		
		Aquatic fish fauna		
13	Aesthetics	Landscape		
Environmental Pollution				
15	Atmosphere	Air pollution		
16	Water	Water pollution		
17	Noise/vibration	Noise and vibration		
Overall evaluation:		Is detail EIA necessary for the project implementation?	Need of EIA?	

Table 2.6 Matrix: Project activities list for the Preliminary Environmental Impact Assessment

Evaluation Key: Environmental assessment matrix (Introduction on reverse side)

P : Potentially significant adverse environmental impact for which a design solution has been identified.

A : Adverse environmental impact that is potentially significant but about which insufficient information has been obtained to make a reliable prediction.

X : Residual and significant adverse environmental impact

E : Significant environmental enhancement.

	Project activities	Pre-construction stage										Construction stage																Operation and maintenance stage						Consequent projects		
	Identification of activities	Access roads	River crossings	Site surveying	Boring test	Site cleaning / Burning	Earthworks	Equipment	Waste disposal & recovery	Land acquisition	Resettlement/compensation	Access roads	River crossing / Detour road	Earth works	Demolition	Building relocation	Reclamation	Erosion control	Drainage alteration	Piling	Structures	Equipment	Revegetation	Landscaping	Labour force	Utilities	Waste disposal & recovery	Equipment	Transportation / Traffic	Pedestrian traffic	Waste disposal & recovery	Accidents	Landscape	Amenities	Utilities	Transportation
Socio-economic Env.	Land aquisition																																			
	Resettlement																																			
	Economic activities																																			
	Employment																																			
	Transportation/traffic																																			
	Public facilities																																			
	Disintegration																																			
	Amenities																																			
	Historic assets																																			
	Cultural properties																																			
	Fishery rights																																			
	Generated waste																																			
	Accidental damages																																			
Natural Env.	Topographic feature																																			
	Geological condition																																			
	Land use																																			
	Soil erosion																																			
	Hydrological feature																																			
	Water use																																			
	Water quality																																			
	Floating debris																																			
	Flood affection																																			
	Terrestrial vegetation																																			
	Terrestrial wildlife																																			
	Aquatic flora																																			
	Aquatic fish fauna																																			
	Landscape																																			
Pollution	Air pollution																																			
	Water pollution																																			
	Noise and vibration																																			

Project No. and Name: Location: Region: Province:

3.6.2 Assessment Decision Making Factors and Criteria

There are six factors that must be taken into account when assessing the significance of an environmental impact arising from a project activity. The factor are interrelated and must not be considered in isolation. For a particular impact some factors may carry more weight than others but it is the combination of all the factors that determines significance.

(1) Magnitude:

This is defined as the probable severity of each potential impact. Will the impact be irreversible? If reversible, what will be the rate of recovery or adaptability of an impact area? Will the activity preclude the use of the impact area for other purposes?

(2) Prevalence:

This is defined as the likely eventual extent of the impact. Each one taken separately might represent a localized impact of small importance and magnitude. Coupled with the determination of cumulative effects is the remoteness of an effect from the activity causing it. The deterioration of fish production resulting from access roads could effect subsistence fishing in an area many miles away, and for months or years after the project activity has ceased.

(3) Duration and frequency:

The significance of duration of frequency is reflected in the following questions. Will the activity be long-term or short-term? If the activity is intermittent, will it allow for recovery during inactive periods?

(4) Risk:

This is defined as the probability of serious environmental effects. To accurately assess the risk both the project activity and the area of the environment impacted must be well known and understood.

(5) Importance:

This is defined as the value that is attached to an environmental component in its present state. Alternatively, the impacted component may be of regional, provincial or even national importance.

(6) Mitigation:

Are solutions to problems available?
Existing technology may provide a solution to a silting problem expected during construction of an access road, or to bank erosion resulting from a new stream configuration.

3.6.3 Possible Assessment Decisions

Using the above criteria is:

(1) No impact

(a) It should be very obvious when a project activity is unlikely to have an impact on an environmental component.
(b) Potential adverse environmental impacts are known but are not considered significant. It is however incumbent on the assessor to seek, either through his own resources or in consultation, an environmentally acceptable design solution.

(2) Unknown and potential adverse impact

If for any activity there is a lack of knowledge on the possible environmental impacts, then the activity should be rated as having unknown significance. The nature of the river crossing (ford, bridge, ferry or causeway) may not yet have been planned and the significance of the environmental impact of that stream crossing is therefore unknown.

(3) Significant impact

Activities and their environmental impacts are judged to be significant if they create, or have the potential to create, concern and controversy in the public or professional community. Since assessment decisions involve elements of individual values, assessors should consider the value which the scientific community and the general public attach to various environmental factors.

3.7 Contents of Preliminary Assessment Report and Format

(1) Project title

The project title should identify the type of project proposed e.g. Bridge project and the general location if it is known. It should state also whether Preliminary Assessment is mandatory according to proper guidelines or is being done voluntarily. The title should indicate too if the project is part of a larger proposal.

(2) Project initiator

A clear statement is required as to what public or private organisation has initiated the project. If the Preliminary Assessment has not been carried out "in house" the name of the consulting or other organisation that carried out the Preliminary Assessment should be given. It should also make quite clear the organisation and the individual to whom any enquires should be directed.

(3) Statement of need

The statement of need should outline the background to the project and the reasons for it being proposed. It should establish a social and/or economic need for the project and should conclude with a definite statement of aim for the project.

(4) Project description

A more detailed description of a selected project option (if one option has been selected during the prefeasibility study) or a detailed description of the project concept (if options have been kept open) should be given here.

As a guide the project description should include:

(a) Description of the project with technical data available.
(b) Maps and diagrams (photographs might also be useful to describe some projects)
(c) A summary of the technical economic and environmental features essential to the project.

(5) Existing environment

The description of the existing environment should identify as appropriate:

(a) The conditions in qualitative and quantitative terms, of the physical, biological and human environment prior to implementation of the project.
(b) The spatial boundaries within the environment are considered.
(c) Environmentally sensitive areas of special or unique scientific, Socio-economic or cultural value.

(6) Project options

Within the constraints of the aim and broad economic, technical and environmental factors there a number of available project options in terms of size, technology, layout raw and materials. The principle features of each option should be given and the economic, technical and environmental advantages and disadvantages of each discussed and evaluated. Included in the discussion should be the "no project" option. This is an opportunity for the assessor to highlight any social, economic or environmental benefits that may accrue from the project and which would be denied to the community if the project was abandoned. If more than one location option is available these too should be discussed and compared. In support of the discussion the matrix used to reach these conclusions should be included.

(7) Residual significant impacts

Using the matrix for reference this section should describe how both beneficial and adverse significant impacts are expected to occur. Consideration should be given to possible cumulative, synergistic or antagonistic environmental effects.

The discussion should state:

(a) The nature of the effect (e.g. air quality)
(b) The source of the impact (e.g. oil fired furnace chimney emission)
(c) The nature of the impact (e.g. human health, visual aesthetics)
(d) Why the impact is judged to be significant or unknown.
(e) In the case of an impact of unknown significance any courses of action considered to assess the impact.

It must be clearly understood that the environmental matrix is not an environmental impact assessment in itself. It performs three important functions however:

1). It assists the project initiator to compare and select from the real project options available.
2). It provides a checklist for the prediction of environmental impacts.
3). It communicates the reader in graphic form the environmental concerns arising from the project proposal.

(8) Mitigating and abatement measures

In this section assessors should discuss all the design measures which have been adopted into the project plan to reduce or to eliminate significant potential environmental impact. The discussion should include on economic evaluation of the design measures adopted and of those considered but rejected.

(9) Summary of conclusions

The project initiator should draw appropriate conclusions in each section of his report. It is useful however, to have the conclusions summarised in a series of brief statements referring to relevant sections of the report.

(10) Sources of data specialist consultations and public participation

Individuals or agencies consulted for specialist knowledge or information used in the report should be referred to in the text and documented in this section. Such documentation should include the person's name and parent organisation, the form of the communication and the date. Field data collection programmes completed by the project initiator or his agent, and the form and extent of public participation during Preliminary Assessment should be reported here. Written opinions received from outside specialists should be appended.

CHAPTER 4 STEPS TOWARDS ENVIRONMENTAL IMPACT ASSESSMENT

4.1 General

To complete an Environmental Impact Assessment (EIA) in an efficient manner and to realise the objectives listed above, the assessor should take the following steps in sequence:

(a) Describe the proposed project as well as the options:

(b) Describe the existing environment:

(c) Select the impact indicators to be used:

(d) Predict the nature and the extent of the environmental effects:

(e) Identify the relevant human concerns:

(f) Assess the significance of the impact:

(g) Incorporate appropriate mitigating and abatement measures into the project plan:

(h) Identify the costs and benefits of the project to the community:

(i) Report on the assessment

This sequence may be repeated for a number of project options and for a selected project concept with mitigating or abatement measures incorporated.

4.2 Consideration of Project Options

An assessment of the project options available is important right from the earliest stages of project planning. The environmental implications of each option should be considered while the options are still open. Major design and project siting options are often assessed and eliminated, and an outline plan formulated in the initial project study.

The assessor should identify all the project siting and major design options available as well as the technical, economic and environmental reasons for selecting a preferred option (see also

4.2.1 Selecting Mitigating and Abatement Measures

A further reason for assessment at an early stage of project planning, is to enable the planner to identify and to incorporate into the plan any design components or modifications which will mitigate or abate potential environmental impacts. However, identification of environmental protection measures is only part of the task. Assessors must also seek to evaluate those measures.

4.2.2 Environmental Data Collection

Environmental data collection may be necessary during environmental impact assessment in order to determine the extent of an environmental effect or to decide how significant to the community a predicted impact is likely to be.

Assessors should seek the information required from environment-related agencies, universities, research institutions and other established sources before embarking on field data collection programmes.

Environment-related agencies, if they are unable to provide the data required for impact assessment, can contribute by advising on the environmental data that assessors need to collect. Environmental data collection programmes must be kept within manageable and economic proportions.

4.2.3 Public Participation

Public participation in the environmental impact assessment procedure is an aid to project planning. It enables the project planner to,

(a) Monitor community needs and ensure that the direction or emphasis of his project continues to satisfy those needs.

(b) Identify both material and psychological impacts of the project on the community,

(c) Measure and promote the social acceptance of the project in the community and avoid costly modification or abandonment of the project at a later stage.

(d) Monitor changing environmental values in the community.

(e) Obtain additional environmental information known to the local population.

A valid assessment of the impact of a project on the community can rarely be made without some form of public participation. However public participation must be carefully planned to obtain the maximum benefit from it.

4.2.4 Costs and Benefits in Environmental Impact Assessment

Even though it may not be possible to place an economic value on environmental losses or gains resulting from a development project, decision-makers (project development bodies) must take into account implied environmental values in their decision-making.

To facilitate the decision-making process therefore, assessors conducting environmental impact assessments must not just identify environmental impacts; they must also provide information on the implied values of the environmental losses and gains.

4.3 Monitoring of the Environmental Impact

During EIA baseline studies may be initiated as part of the environmental data collection programme. Where significant residual environmental impacts are predicted there may be a need for the project initiator to continue these studies as part of a monitoring programe, at least until the early stages of project operation. Such programmes perform two important functions:

(a) They provide a check on the environmental management of the project and ensure that the project initiator meets the conditions attached to the approval given for his project.

(b) They provide feedback to improve the database for environmental impact prediction in future project planning.

4.4 Outline of the Procedure

The environmental impact assessment procedure is shown in Figure 2.2 and summarised procedure shown in Table 2.7. It provides for:

(1) Preliminary Assessment of all Prescribed Activities
(2) Detailed Assessment of those Prescribed Activities for which significant residual environmental impacts have been predicted in the Preliminary Assessment
(3) Review of Detail Assessment Reports.

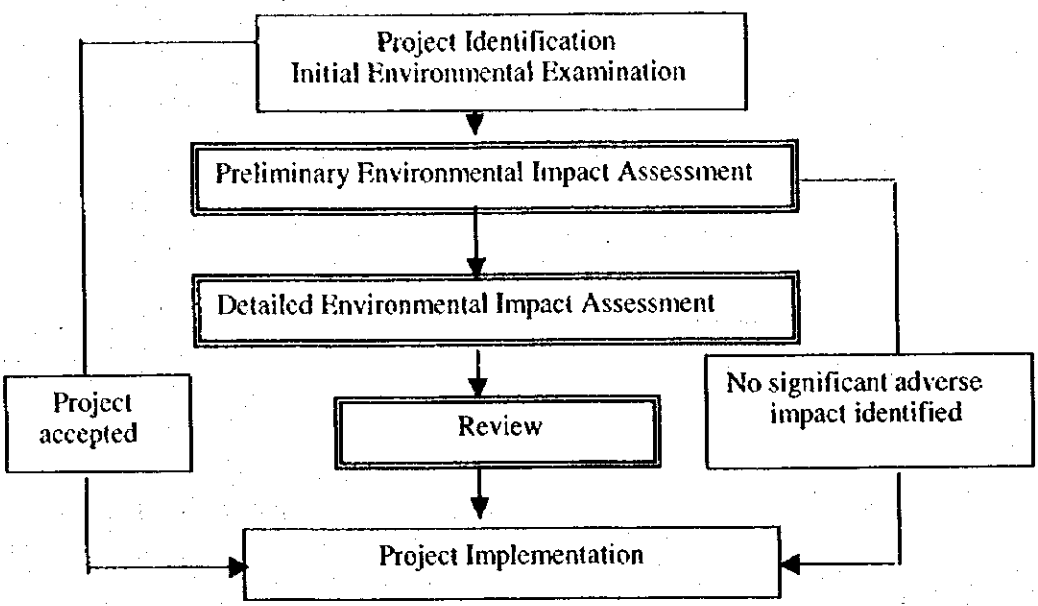


Figure 2.2 Environmental Impact Assessment Procedure

Table 2.7 Summarised Procedure for Environmental Impact Assessment

	Item		Explanation
1	**Aim:**		To assess the overall impact on the environment of development project.
2	**Preliminary Assessment:**		
	Objectives:	For selected project:	To examine and select from the project options available
			To identify and incorporate into the project plan appropriate abatement and mitigation measures.
			To identify the significant residual environmental impacts
	Description:		Standard guidelines issued by the Review Board
			Initiate at an early stage of project planning
			Resources required are a small preparation of those committed to the prefeasibility study
			Some form of public participation is required.
			Uses a prepared matrix as assessment tool
			Environmental data collection may be necessary
			A report is required.
3	**Detailed Assessment:**		
	Objectives:	For project with potentially significant residual environmental impact:	To describe the significant residual environmental impacts predicted from the final project plan.
			To specify mitigating and abatement measures in the final project plan.
			To identify the cost s and benefit of the project to the community
	Description:		Standard guidelines and specific terms of reference for each project are issued.
			Continues through the cause of the detailed study of the project
			Resources required are a small proportion of those committed to the feasibility study
			Some form of public participation is required.
			The assessment method is selected according to the matter of the project
			Environmental data collection is required.
			A report is required.
4	**Review:**		
	Objectives:	For projects subjected to Detailed Assessment	To critically review the Detail Assessment Report
			To evaluate development and environmental costs and benefits in the final project plan.
			To formulate supported recommendations to the project approving on the implementation of the project
	Description:		The review is conducted by an independent Review Board appointing by and responsible directly to the Minister responsible for the environment
			Comment is invited from concerned environment-related agencies and from the public.
			Recommendations are forwarded to the approving authority except when the project initiator selects to revise or abandon his project.
			A maximum period of two months is allowed for review.

4.5 Environmental checklist for possible use by high level decision makers

(1) Impact Identification

a) Does the project have an impact on any environmentally sensitive areas?
b) Is there a clear statement of the significant beneficial and adverse environmental effects of the project? Have the risks been evaluated?
c) Has attention been paid to offsite effects (so-called upstream and downstream effects) including transboundary effects, and to the possible time lag before effects is exhibited?

(2) Mitigation Measures

a) What mitigation measures are proposed and what alternative sites have been considered?
b) What lessons from previous similar projects have been incorporated into the environmental assessment of this project?
c) Have concerned populations and groups been involved and have their interests been adequately taken into consideration in project preparations? Is resettlement involved? Are appropriate compensatory measures envisaged?

(3) Procedures

a) How have environmental guidelines used by the agency and the recipient government been taken into consideration?
b) In which phases of the decision-making process has the environmental assessment been included?
c) How have the beneficial and adverse environmental effects of the project been integrated into the economic analysis of the project?

(4) Implementation

a) Do developing bodies need strengthening to make the environmental measures effective, and, if so, what action is foreseen?
b) How and by whom will the environmental impact and mitigation measures be monitored during and after implementation?
c) Have needed environmental measures been cost and are there adequate and realistic assurances for their funding?

CHAPTER 5 GLOSSARY OF TERMS

5.1 Glossary of Major Environmental Terms

Assessor

The assessor is the person who conducts or coordinates an environmental impact assessment. He may be the leader of a team of experts and he is responsible to the Project Initiator.

Baseline Studies

Baseline studies are fundamental surveys of the Socio-economic, Natural environment and environmental Pollution. They may be specific to a particular project or they may be to provide a database for future environmental assessment at other localities.

Environmental Characteristics

Environmental characteristics are broad environmental categories, such as noise, species and populations and wealth and safety.

Environmental Consideration

To study whether a development project will have serious environmental impacts on the project site and its surrounding areas, analyze the study results, and establish necessary measures for avoiding or alleviating any adverse environmental impacts.

Environmental Components

Environmental components are the detailed environmental categories.

Environmental Effect

A process that is modified by human's actions

Environmental Impact

The undesirable effect on the existing overall conditions of air, water, soil, and living things, assets, social information and circulation of goods, which are related to human life, or on their combined structures.

Environmental Impact Assessment (EIA)

To study, forecast, and evaluate more details the environmental impacts of a development project, which is judged a detailed environmental examination, and to propose the establishment of an environmental protection standard and measures for avoiding or alleviating environmental impacts.

Environmental Management Plan

To formulate an environmental monitoring system or methods based on the environmental protection standard to monitor the project's environmental impacts on surrounding areas, aiming at adequately protecting the environment both during and after project implementation.

Environmental Values

Sectors and individuals within the community have different attitudes, and attach varying importance to environmental quality. The attitude of a community, a sector of the community or an individual to environmental quality is its, or his, environmental values.

Feasibility Study (F/S)

The study for evaluating the possibility, adequacy, and investment efficiency of a project. In general, it attempts to objectively verify the feasibility of a project from social, technical, economic, and financial viewpoints.

Initial Environmental Examination (IEE)

The examination is to be undertaken at the outset of the development project planning stage in order to determine the environmental impacts, which may be created by the particular project, that shall be based on existing information and data as well as easily accessible information relating to the particular project. And also it shall be required proper comments and judgements of specialists who are familiar with the environmental impacts of past similar projects. This examination should be carried out in a short period with a low cost.

IEE has the following two objectives:

(a) To evaluate whether EIA is necessary for the project and, if so, to define its contents;

(b) To examine, from an environmental viewpoint, the measures for alleviating the effects of the project which requires environmental consideration but not a full-scale environmental impact assessment.

Impact Indicator

An element or parameter of the environment that provides a measure of the magnitude of an environmental impact

Master Plan Study (M/P)

The study for preparing the basic plans for various developments projects. In general, it is sector, or for each project.

Matrix

A matrix is a 2 dimensional checklist of environmental components and project activities used to identify and communicate the potential environmental impacts of proposed projects.

Mitigation and Abatement Measures

There are measures adopted into the final project plan, which either moderate or completely forestall a potential environmental impact.

Preliminary Environmental Impact Assessment (Pre-EIA)

Pre-EIA is the first phase of the environmental impact assessment procedure. Selected projects only are subjected to Pre-EIA, which is judged a preliminary environmental examination, and to propose the establishment of an environmental protection standard and measures for avoiding or alleviating environmental impacts.

Preliminary Environmental Survey

The environmental survey conducted during the preparatory study stage of a development project. This includes screening and scoping of the environmental impacts of a particular project. This survey is regarded as a component of the initial environmental examination.

Project Activity

A project activity is an operation or procedure conducted during the planning, development or subsequent operation of the project. Several project activities during each stage of the project adequately describe the work carried out.

Project Description (PD)

The major content and feature of the project: It includes the background of the project (including its upper level plan), the objectives, the executing agency, the beneficiary population, and the project scale.

Preparatory Study

To examine the contents of the full-scale study of a project, and to discuss the scope of work (S/W) of the full-scale study. This study is conducted at the preparatory stage of the project prior to conducting the full-scale study including the master plan and the feasibility study.

Project Identification

Project identification is the inception of project planning. It is usually documented in a very brief report, internal minute or file note. At that stage of planning only the broad project concept and some general ideas on siting are known.

Project Initiator

The project initiator is the proponent of the project. The planning and implementation may be delegated to a consultant or some other agency but for the environmental impact assessment of his project.

Project Options

There are 2 types of option to be considered in environmental impact assessment. They are:
(a) Major design options
(b) Site (Project location) options.

Public Participation

Public participation in project planning is a means of:
(a) Identifying the material or psychological impact of proposal.
(b) Measuring and promoting the social acceptance of a project.
(c) Monitoring community needs and ensuring that development continues to meet those needs.

(d) Monitoring changing environmental value in the community.

Residual Environmental Impact

A residual environmental impact is the potential impact remaining after mitigating measures have been adopted into a project plan.

Review

Review is the third and final phase of the EIA procedure. A Review Board conducts it, which make recommendations on the implementation of the project to the project approving authority.

Scoping

To identify the important environmental impacts among those which can be caused by the implementation of a development plan or development project, and to define the study items of the IEE or EIA based on the findings.

Screening

To evaluate whether or not it will be necessary to include an environmental consideration in a development project. Screening conducted in Japan before the preparatory study is called preliminary screening.

Site Description (SD)

The compact description of the project site, which includes the natural and social environmental conditions in the areas that, may be affected by the project.

Significant Environmental Impact

A significant environmental impact is one that will have an appreciable effect on the quality of life of people in the community or an appreciable effect on the ecosystem on which the community depends.

DIVISION III

BRIDGE INSPECTION AND REHABILITATION

DIVISION III BRIDGE INSPECTION AND REHABILITATION

CONTENTS

DIVISION III BRIDGE INSPECTION AND REHABILITATION

CHAPTER 1 BRIDGE INSPECTION

1.1 Categories of Inspection

Generally, bridge inspection is carried out in various categories, according to the situation and purpose.

a. Routine Inspection

All bridges are included in the routine inspection, which is conducted in conjunction with the routine road inspection. This is for early discovery of any defects and is conducted as a solely visual inspection.

b. Periodic Inspection

All bridges are included in the periodic inspection, which is conducted at regular intervals of time to ensure overall structural safety. This is chiefly a visual inspection but sometimes includes the use of simple tools or instruments.

c. Special Inspection

An special inspection is necessary when any bridge experiences an earthquake, unusual flooding incident; or if special bridge rehabilitation or reconstruction/replacement program is predicted. When an emergency situation has been detected in the process of routine or periodic inspection, a special check-up is required to confirm the safety of the bridge in question.

1.2 Procedures of Inspection

1.2.1 Bridge Inspection Unit

(1) Duties of Inspection Unit

The chief of bridge inspection unit will be given the responsibility for bridge inspection, reporting and inventory. Further the chief of the unit shall be responsible for the thoroughness of the bridge inspection, the analysis of all findings ascertained by the Inspection Teams and the subsequent recommendations for corrections of defects, posting of restriction of loads or speeds, or any other recommendations deemed necessary.

In such situation, the chief of unit must be thoroughly familiar with the design and construction features of the bridge to properly interpret what is observed and reported. This means that the chief of unit must be capable of determining the safe load carrying capacity of the structure and be able to recognize any structural deficiency, and assess its seriousness to keep the bridge in a safe condition. An important point is to recognize areas of a bridge where the problem is incipient so that preventive maintenance can be properly programmed.

Since it is not possible for anyone person to have all the appropriate experience to be an expert in all the specialized aspects of bridge engineering, the Bridge Department Chief must make available additional support from the other specialized engineers in fields such as structural design, construction, materials, maintenance, soils or emergency repairs such as flood fighting or scouring prevention.

(2) Bridges Inspectors

Bridge Inspectors may be recruited from people having one of the following qualifications:

- 5 Years post-graduation experience from University; and
- 10 Years experience after graduation from Technical College.

An inspection team should comprise at least:

- A bridge inspector;
- An inspector's assistant, as required;
- A chain-man; and
- 2 ladder men/flag-men, as required.

(3) Inspection Tools

The Inspection Team should be provided with:

- Traffic warning devices (flags, cones, flashing beacons etc.);
- Camera;
- Binoculars (for inspection from a distance);
- Flashlight;
- Marking chalk;
- Chipping hammers;
- Paint scrapers and steel hammer;
- Calipers;
- Plumb-bob and line;
- Measuring tapes and other tools/instruments (refer to Inspection Manual); and
- Suitable vehicle or small boat.

(4) **Safety**

Before any inspection starts, due consideration must be given to the personal safety of the inspection team. If the inspection requires the closing of the traffic lane the responsible Police Authority must be informed and suitable police protection provided.

Adequate warning devices should be erected when required and other safety measures should be observed to provide a warning to motorists that work is in progress, both to protect the inspection team and the motorists. When inspecting bridge components, care must be taken to ensure that tools, equipment, loose concrete or debris do not fall onto the roadway.

1.2.2 Bridge Components to be Inspected

A general plan/evaluation should be drawn up so that each bridge component can be recorded systematically. Bridges will be first classified into concrete or steel or wooden structure. The component of the bridge, such as superstructure (beams and deck structure), substructure (abutments and piers), foundations, bridge railing/hand rails, sidewalk, and bridge accessories (bearing and joints) can be indexed and this identification method will eliminate unnecessary descriptions and provide a clear and efficient method of provision of data to personnel receiving the bridge inspection reports.

Inspection items are generally classified by types of structures and materials as follows:

Bridge Component			Inspection Item (damage)
Superstructure	Steel Component	Main Girder	Aging of Coat, Rusting, Loosening, Falling off, Deformation, Cracking
		Cross Frame	
		Stringer	
		Bracing	
		Lateral Bracing	
	Concrete Component	Main Beam	Cracking, Honeycombs, Scaling, Spalling, Wear, Breakage, Delamination, Efflorescence,
		Cross Beam	
		Slab	
	Timber Component	Main Beam	Decay, Cracking, Deflection, Sagging, Loosening
		Cross Beam	
		Slab	
Substructure	Steel Component	Pier	Aging of Coat, Rusting, Loosening, Falling off, Deformation, cracking
	Concrete Component	Abutment and Pier	Cracking, Honeycombs, Scaling, Spalling, Wear, Breakage, Delamination, Efflorescence
	Timber Component	Abutment and Pier	Decay, Cracking, Deflection, Sagging, Loosening,
Foundation			Settlement, Sliding, Inclination, Scoring
Bearing	Steel Component		Aging of Coat, Rusting, Movement,
	Elastomeric Component		Change of Color, Deformation
Pavement	Asphalt and Concrete		Difference in Level, Pot Hole, Cracking
Hand Railing	Steel Component		Aging of Coat, Rusting, Loosening, Falling off, Deformation, Cracking
	Concrete Component		Cracking, Honeycombs, Scaling, Spalling, Wear, Breakage, Delamination, Efflorescence,
	Timber Component		Decay, Cracking, Deflection, Sagging, Loosening
Expansion Joint	Steel Component		Aging of Coat, Rusting, Loosening, Falling off, Deformation, Cracking, Trouble of Gap, Difference in Level
	Elastomeric Component		Change of Color, Deformation, Trouble of Gap, Difference in Level

1.2.3 Major Damages to be Inspected

Major damages to be inspected are defined as follows:

(1) Damages of concrete structure

① Cracking

Cracks of concrete are classified as structural or non-structural cracks. Structural cracks are caused by load stresses and are divided into flexure and a shear cracks. Flexure cracks are vertical and start in the maximum tension zone and proceed toward the compression zone. Shear cracks are found near the bearing area and begin at the bottom of the member and extend diagonally upward.

Non-structural cracks are divided into temperature, shrinkage and mass concrete cracks. These cracks are relatively minor and generally do not affect the load carrying capacity of the member.

They can, however, provide openings for water and contaminants which can lead to serious problems.

② Scaling/Spalling

Appearances of scaling and spalling are similar but their causes are different. Scaling is the gradual and continuing loss of surface mortar and aggregate over an area. A spall is a roughly circular or oval depression in the concrete resulted from separation and removal of a portion of surface concrete. Spalls can be caused by corroding reinforcement and friction from thermal movement. Reinforcing steel is often exposed.

③ Delamination

Delamination occurs when layers of concrete separate at the level of outermost layer of reinforcing bars. The major cause of delamination is expansion of corroding reinforcing bars. This is commonly caused by intrusion of chlorides or salt. Delaminated areas give a hollow sound when tapped with a hammer. The resulting depression by delamination is called a spall.

④ Efflorescence

Efflorescence is a white deposit on concrete caused by precipitation of soluble salts brought to the surface by capillary action of moisture in concrete. Efflorescence is a sign of the concrete contaminated.

⑤ Cracking

Cracks of concrete are classified as structural or non-structural cracks. Structural cracks are caused by load stresses and are divided into flexure and a shear cracks. Flexure cracks are vertical and start in the maximum tension zone and proceed toward the compression zone. Shear cracks are found near the bearing area and begin at the bottom of the member and extend diagonally upward.

⑥ Wear/Abrasion

Wear and abrasion of the concrete surface are caused by being exposed to traffic and water flow. Abrasion damage is the result of external forces acting on the surface of concrete member like erosive action of sands in running water over the concrete surface.

⑦ Breakage

Breakage is a damage of destruction of concrete members caused by collision of vehicles, boats or other external force on bridge components.

(2) Damages of steel structure

① Aging of Coat

As paint coat ages after its application, the paint coat loses coherence to steel material and then peels off finally. This will cause rusting on the steel. Usually the paint coat must be maintained and paint has to be reapplied periodically, once a ten or twenty years depending on the characteristics of the paint materials and the environment.

② Rusting

Rusting damage will occur on all kinds of steel in bridges and will increase with time. Beam, girder, or floor beam top flanges in contact with or encased by deteriorated or chloride-contaminated concrete creates a suitable environment for steel corrosion loss.

③ Loosening and Falling off

Bolts tightened incorrectly may be loosened later and fall off.

④ Deformation

Steel is commonly used in this sections, but in this form it is vulnerable to buckling under compressive load, and thus slender components may be bent by the buckling. On structures over streams an impact damage can occur by moving ice or debris during period of flood. On through girder bridges, the top flange, web stiffeners, and knee braces are also subject to damage from roadway traffic. Any crack or fracture in a steel beam should be considered a sign of serious distress, and should be approached with immediate corrective action.

⑤ Cracking

The most common causes of cracking are fatigue and poor detailing practice. Fatigue begins with improper fabrication and welding details and proceeds with load stress variation and reversal until a final failure mode, such as brittle fracture or buckling, is manifested.

(3) Damages of timber structure

① Decay

Decay appears as a moist area with stain or discoloration. A major cause of decay is living fungi.

② Split/Check

Check is a separation of the wood fibers, normally occurring across the annual growth rings. Split is similar to check except the separations of the wood fibers extend completely through the piece of wood.

③ Sagging

sagging is excessive deflection under live load and significant permanent sagging is a sign of structural weakness.

④ Loosening

Loosening of connections is generally caused by shrinkage of wood, decay, or crushing of wood around fastener.

1.3 Rating System for Bridge Conditions

1.3.1 Numerical Rating System

The numerical rating system is used to rate bridge components.

Rating	Condition in general
Rank I	"Dangerous" condition, bridge already closed, conditions beyond repair, imminent danger of collapse or already collapsed.
Rank II	"Potentially hazardous" condition, such a rating in primary members implies there is a danger of collapse under any further use of this structure and bridge should be closed to traffic immediately. When such rating applies to secondary elements, it can be cause of vehicular or pedestrian accidents and should be corrected immediately. The element of the Rank must be repaired.
Rank III	"Not Functioning as Originally Designed" condition, sufficient to reduce the elements structural capacity and its ability to function as designed. When this rating applies to primary elements, the bridge must have the maximum design loading reduced accordingly. Immediate repair must be made to return the structure to the design capacity.
Rank IV	"functioning as Originally Design" condition, insignificant deterioration or distress does not reduce the capacity of the elements under inspection nor their ability to function. For example, an expansion joint or bearing which are corroded but have not lost any effective strength and still permits the required movements. Minor repair can be made to alleviate distress or eliminate deterioration.
Rank V	"Good, New or like New" conditions, no sign of distress or deterioration. No repairs necessary.
NA	Not applicable
U	Unknown

1.3.2 Rating System for Damage Rank

To rate damage rank (I through V), the Bridge Inspection Guidelines (1988 Proposal) of the Civil Engineering Institute of Japan's Ministry of Construction is introduced.

The system adopts the following three factors to rate the rank (I through V) of a damage.

① Location or pattern of damage (X)
② Depth or width of damaged part (Y)
③ Extent of damaged part (Z)

Each factor is evaluated by the magnitude of damage namely Large (or Deep), Medium, or Small (or Shallow). The rank of damage is decided based on a combination of the three factors by referring to the prescribed damage rank table. The rating factors and rank tables for major damages of concrete, steel and timber bridges are given as follows:

(1) Concrete Members

① Cracks on beams and substructures

Rating Factor	Evaluation of Factor		
	Large	Medium	Small
Location or pattern (X)	Critical part	-	Uncritical part
Width (Y)	· RC-member $Y \geqq 0.3mm$ · PC-member $Y < 0.3mm$	· RC-member $0.3mm > Y \geqq 0.2mm$ · PC-member $0.1mm > Y \geqq 0.1mm$	· RC-member $Y < 0.2mm$ · PC-member $Y < 0.1mm$
Extent (Z)	Z>50cm	-	Z≦50cm

Damage Ranks

X	Y	Z	Secondary Member	Primary Member	X	Y	Z	Secondary Member	Primary Member
Large	Large	Large	II	II	Small	Large	Large	II	II
		Small	III	II			Small	III	III
	Medium	Large	IV	III		Medium	Large	IV	IV
		Small	IV	III			Small	IV	IV
	Small	Large	V	V		Small	Large	V	V
		Small	V	V			Small	V	V

② Cracks on slab

Rating Factor	Evaluation of Factor		
	Large	Medium	Small
Location or pattern (X)	Two directions	-	One direction
Width (Y)	· Cracks filled with dust · Y≧0.3mm	· Accompanied with leakage water or efflorescence · 0.3mm>Y≧0.2mm	· Crack line only · Y<0.2mm
Extent (Z)	Z>50cm	-	Z≦50cm

Damage Ranks

X	Y	Z	All Member	X	Y	Z	All Member
Large	large	Large	Ⅱ	Small	Large	Large	Ⅲ
		Small	Ⅱ			Small	Ⅲ
	Medium	Large	Ⅱ		Medium	Large	Ⅲ
		Small	Ⅲ			Small	Ⅳ
	Small	Large	Ⅲ		Small	Large	Ⅳ
		Small	Ⅳ			Small	Ⅳ

③ Scaling/spalling, honeycombs and delamination

Rating Factor	Evaluation of Factor	
	Large	Small
Location or Pattern (X)	-	-
Width (Y)	· Reinforcement exposed	No reinforcement exposed
Extent (Z)	· Damaged area is large · Superstructure Z≧0.1m2 · Substructure Z≧1.0m2	· Damaged area is small · Superstructure Z<0.1m2 · Substructure Z<1.0m2

Damage Ranks

Y	Z	Secondary Member	Primary Member
Large	Large	Ⅱ	Ⅱ
	Small	Ⅳ	Ⅲ
Small	Large	Ⅳ	Ⅲ
	Small	Ⅳ	Ⅳ

④ Efflorescence

Rating Factor	Evaluation of Factor	
	Large	Small
Location or Pattern (X)	-	-
Width (Y)	-	-
Extent (Z)	· Damaged area is large · Superstructure $Z \geq 0.1m2$ · Substructure $Z \geq 1.0m2$	· Damaged area is small · Superstructure $Z < 0.1m2$ · Substructure $Z < 1.0m2$

Damage Ranks

Z	Secondary Member	Primary Member
Large	II	II
Small	IV	IV

⑤ Wear

Rating Factor	Evaluation of Factor	
	Large	Small
Location or pattern (X)	-	-
Width (Y)	Damage reaches to reinforcement	Damage does not reach to reinforcement
Extent (Z)	Damaged area is large $Z \geq 1.0m2$	Damaged area is small $Z < 1.0m2$

Damage Ranks

Y	Z	All Members
Large	Large	II
	Small	III
Small	Large	III
	Small	IV

⑥ Breakage

Rating Factor	Evaluation of Factor	
	Large	Small
Location or pattern (X)	-	-
Width (Y)	Excessive damage	Observed damage
Extent (Z)	-	-

Damage Ranks

Y	All Members
Large	II
Small	IV

(2) Steel Members

① Aging of Coat

Rating Factor	Evaluation of Factor	
	Large	Small
Location or Pattern (X)	-	-
Width (Y)	Paint is peeling off	Discoloration of paint
Extent (Z)	Total area	Local area

Damage Ranks

Y	Z	All members
Large	Large	Ⅲ
	Small	Ⅳ
Small	Large	Ⅳ
	Small	Ⅴ

② Rusting

Rating Factor	Evaluation of Factor	
	Large	Small
Location or pattern (X)	-	-
Width (Y)	Loss of steel material	Rusting on steel surface
Extent (Z)	Total area	Local area

Damage Ranks

Y	Z	Secondary Member	Primary Member
Large	Large	Ⅱ	Ⅱ
	Small	Ⅲ	Ⅱ
Small	Large	Ⅲ	Ⅱ
	Small	Ⅳ	Ⅲ

③ Loosening

Rating Factor	Evaluation of Factor	
	Large	Small
Location or Pattern (X)	-	-
Width (Y)	-	-
Extent (Z)	· Connection plate: large · Anchor bolt: excessive loosening · Over 10% loosening at one connection plate	· Connection plate: small · Anchor bolt: observed loosening · Less 10% loosening at one connection plate

Damage Ranks

Z	All members
Large	Ⅱ
Small	Ⅳ

④ Falling off

Rating Factor	Evaluation of Factor	
	Large	Small
Location or pattern (X)	-	-
Width (Y)	-	-
Extent (Z)	· Connection plate: large · Over two pieces falling off	· Connection plate: small · One pieces falling off

Damage Ranks

Z	All member
Large	Ⅱ
Small	Ⅲ

⑤ Deformation

Rating Factor	Evaluation of Factor	
	Large	Small
Location or pattern (X)	-	-
Width (Y)	Excessive deformation	Observed deformation
Extent (Z)	-	-

Damage Ranks

Y	All member
Large	Ⅱ
Small	Ⅳ

⑥ Cracking

Rating Factor	Evaluation of Factor	
	Large	Small
Location or pattern (X)	-	-
Width (Y)	Observed cracking	-
Extent (Z)	-	

Damage Ranks

Y	All Member
Large (Cracking is observed)	Ⅱ

(3) Timber Members

① Decay and Deflection/Sagging

Decay			Deflection/Sagging		
Rating Factor	Evaluation of Factor		Rating Factor	Evaluation of Factor	
	Large	Small		Large	Small
Extent (Z)	Excessive damage	Observed damage	Width (Y)	Visible deflection	Observed deflection

Damage Ranks

Decay			Deflection/Sagging		
Z	Secondary Member	Primary Member	Y	Secondary Member	Primary Member
Large	Ⅲ	Ⅱ	Large	Ⅱ	Ⅱ
Small	Ⅳ	Ⅲ	Small	Ⅳ	Ⅲ

② Split/Check

Rating Factor	Evaluation of Factor	
	Large	small
Location or pattern (X)	Whole area	Local part
Width (Y)	Visible	Observed

Damage Ranks

X	Y	Secondary Member	Primary Member
Large	Large	Ⅲ	Ⅱ
	Small	Ⅲ	Ⅲ
Small	Large	Ⅳ	Ⅳ
	Small	Ⅳ	Ⅳ

(4) Foundation

① Settlement

Rating Factor	Evaluation of Factor	
	Large	small
Width (Y)	Can be seen settlement. Supporting point settlement; Simple Beam : 25mm over Continuous : 1/2000 mm over	Suspected settlement. Supporting point settlement; Simple Beam : 25mm less Continuous : 1/2000 mm less

Damage Ranks

Y	Ranking
Large	Ⅱ
Small	Ⅲ

② Sliding

Rating Factor	Evaluation of Factor	
	Large	small
Width (Y)	Can be seen sliding. Being slide due to lateral ground flow.	Be suspected sliding. Being slide due to lateral ground flow.

Damage Ranks

Y	Ranking
Large	II
Small	III

③ Inclination

Rating Factor	Evaluation of Factor	
	Large	small
Width (Y)	Can be seen inclination. Being incline due to lateral ground flow.	Be suspected inclination. Being incline due to lateral ground flow.

Damage Ranks

Y	Ranking
Large	II
Small	III

④ Scour

Rating Factor	Evaluation of Factor	
	Large	small
Location or pattern (X)	Direct Foundation	Pile Foundation Caisson Foundation
Width (Y)	Scouring in severe. Be scoured in severe by water flow.	Can be seen scouring Be scoured by water flow

Damage Ranks

X	Y	Ranking
Large	Large	II
	Small	II
Small	Large	II
	Small	III

1.4 Inspection Forms

The following sample inspection forms are recommended.

Form-1: General Information
(a) Administrative Data
(b) Geography
(c) River condition

Form-2: Structural Details
(a) Superstructure
(b) Substructure
(c) Foundation
(d) Accessories

Form-3: Damage Inspection
(a) For Concrete Member
(b) For Steel Member
(c) For Timber Member

Inspection Form-1: General Information

	Record	Unit
Bridge No.		
Bridge Name		
Region		
Province		
Link No.		
Road No.		
Road Name		
Distance from Road Origin		km
Load Limit of Bridge		ton

	Record						
Earthquake	Yes			No			
Topography	Mountainous		Hill		Flat		

	Record	
Population		
Distance to Main City		km
Income		US $

	Record					
River Name						
River Width						m
Velocity of Flow						m/sec
Meandering	Yes		No			
Present Water Level	Depth from Deck Surface					m
Highest Water Level	Depth from Deck Surface					m
Erosion of Bank	Yes		No			
Obstacles in River						
Driftwood	Yes		No			
Condition of River Bed	Rock	Boulder	Gravel	Sand	Silt	

	Record						
Detour	Yes			No			
Public Facility	Hospital		School		Public Hall		
Land Use	Farm	Agriculture	Grass Land	Industrial	Resident	City	
Closed Period to Traffic							Month

Sketch and Comment

Inspection Form-2: Structural Details

Bridge Type		
Component		Record
Superstructure	Beam	
	Slab	
Substructure	Abutment	
	Pier	
Foundation		
Pavement		
Accessories	Bearing	
	Expansion Joint	
	Hand Railing	

Structural Dimension			
		Record	Unit
Bridge Length			m
Span Length			m
Bridge Width	Total Width		m
	Effective Width		m
	Side Walk		m
Number of Lane			No.
Superstructure	Beam Depth		m
	Number of Beam		No.
	Spacing of Girder		m
	Thickness of Slab		cm
Substructure	Number of Pier		No.
	Height of Pier		m
	Height of Abutment		m

Sketch and Comment

Inspection Form-3: Damage Inspection (for Concrete Member)

Bridge No.		Bridge Name		Date		Inspector	

Structural Component and Location	Damage	Location/Pattern(X)		Width(Y)			Extent(Z)		Quantity	Unit
		Large	Small	Large	Medium	Small	Large	Small		
Superstructure(Beam) Substructure(Abutment, Pier, Foundation) Hand-Railing	Cracking	Critical Part	Uncritical Part	Large Cracking	Medium Cracking	Small Cracking	Small Space	Large Space		m^2
	Honeycombs			Exposed Re-Bar		No Exposed Re-Bar	Large Area	Small Area		m^2
	Scaling			Exposed Re-Bar		No Exposed Re-Bar	Large Area	Small Area		m^2
	Spaling			Exposed Re-Bar		No Exposed Re-Bar	Large Area	Small Area		m^2
	Wear			Reach to Re-Bar		Not Reach to Re-Bar	Large Area	Small Area		m^2
	Breakage			Excessive Damage		Observed Damage				m^2
	Delamination			Exposed Re-Bar		No Exposed Re-Bar	Large Area	Small Area		m^2
	Efflorescence						Large Area	Small Area		m^2
Superstructure(Slab)	Cracking	Two Direction	One Direction	Large Cracking	Medium Cracking	Small Cracking	Small Space	Large Space		m^2

Comment

Inspection Form-3: Damage Inspection (for Steel Member)

Bridge No.		Bridge Name		Date		Inspector	

Structural Component and Location	Damage	Location/Pattern(X)		Width(Y)			Extent(Z)		Quantity	Unit
		Large	Small	Large	Medium	Small	Large	Small		
Superstructure(Girder, Frame, Stringer, Bracing) Substructure(Pier), Hand Railing	Aging of Coat			Paint is Peeling off		Discoloration of Paint	Total Area	Local Area		m^2
	Rusting			Steel Material Loss		Steel Surface	Total Area	Local Area		m^2
	Loosening						Large Part	Small Part		m^2
	Falling off						Large Part	Small Part		m^2
	Deformation			Excessive		Observed				m^2
	Cracking			Observed		Discoloration of Paint	Total Area	Local Area		m^2
Bearing	Aging of Coat			Paint is Peeling off		Steel Surface	Total Area	Local Area		m^2
	Rusting			Steel Material Loss						m^2
	Movement			Excessive		Observed				m^2
Expansion Joing	Aging of Coat			Paint is Peeling off		Discoloration of Paint	Total Area	Local Area		m^2
	Rusting			Steel Material Loss		Steel Surface	Total Area	Local Area		m^2
	Deformation			Excessive		Observed				m^2
	Trouble of Gap			Observed						m^2
	Difference in Level			Excessive		Observed				m^2

Inspection Form-3: Damage Inspection (for Timber Member)

Bridge No.		Bridge Name		Date		Inspector	

	Damage	Location/Pattern(X)		Width(Y)			Extent(Z)		Quantity	Unit
		Large	Small	Large	Medium	Small	Large	Small		
Superstructure(Beam, Slab) Substructure(Abutment, Pier) Hand-Railing	Decay						Excessive	Observed		m^2
	Cracking	Whole Area	Local Area	Visible	Observed					m^2
	Deflection						Excessive	Observed		m^2
	Sagging						Excessive	Observed		m^2
	Loosening						Large Part	Small Part		m^2

CHAPTER 2 BRIDGE REHABILITATION

2.1 Damage Types and Repair Methods

Major damages and their repair methods are as follows:

	Damages	Repair Methods		Materials
Concrete	Live Cracks	Caulking		Elastomeric sealer
		Pressure injection with flexible filler		"Flexible" epoxy filler
		Jacketing	Strapping	Steel wire or rod
			Overlaying	Membrane or special mortar
	Dormant Cracks	Caulking		Cement grout or mortar, Fast-setting mortar
		Pressure injection with rigid filler		"Rigid" epoxy(resin and hardener mix) filler
		Coating		Bituminous coating, tar
		Overlaying		Asphalt overlay with membrane
		Grinding and overlay		Latex modified concrete, highly dense concrete
		Dry-pack		Dry-Pack
		Shotcrete/ Gunite		Mortar(cement), Fast-setting mortar
		Patching		Cement mortar, Epoxy or Polymer concrete
		Jacketing		Steel rod
	Honeycomb Delamination Wear Breakage	Dry-Pack		Dry-pack
		Patching		Portland cement grout, mortar, cement
		Resurfacing		Epoxy or Polymer concrete
		Shotcrete/Gunite		Fast-setting mortar
		Pre-placed aggregate		Coarse aggregate and grout
	Scaling	Overlaying		Portland cement concrete, Latex modified concrete, Asphalt cement, Epoxy or polymer concrete
		Grinding		---
		Shotcrete/Gunite		Fast-setting mortar, Cement mortar
		Coating		Bituminous, Linseed oil coat, Silane treatment
	Spalling	Patching		Concrete, Epoxy, Polymer, Latex, Asphalt
		Shotcrete/Gunite		Cement mortar, Fast-setting mortar
		Overlay		Latex modified concrete, Asphalt concrete, Concrete
		Coating		Bituminous, Linseed oil, Silane
	Efflorescence	Grinding		---
		Overlaying		Asphalt Cement or Concrete, Concrete, Concrete, Epoxy/Polymer/Latex modified concrete
		Coating		Bituminous, Linseed oil, Silane, Cement concrete
		Resurfacing		Epoxy/ Polymer concrete
		Shotcrete/Gunite		Cement Concrete, Cement Mortar
		Patching		Concrete, Epoxy, Polymer, Asphalt, Latex

	Damages	Repair Methods	Materials or Tools
Steel	Aging of Coat	Cleaning	Sand brush, Electric wire brush
		Repainting	Oil/Alkyd
		Replacing	Replace new
	Rusting	Cleaning	Sand brush, Electric wire brush
		Repainting	Oil/Alkyd
		Replacing	Replace new
	Loosening	Re-tightening	Torque Wrench
	Falling Off	Replacing	Replace new
	Deformation	Reforming	Heating , Pressuring
		Replacing	Replace new
	Crack	Welding	---
		Splicing	---
		etc	---
Timber	Decay	Replacing	---
		Coating	Coal-Tar Creosote
		Injection	Synthetic resin
	Split/Check	Replacing	---
	Deflection/ sagging	Replacing	---
	Loosening	Replacing	---
		Re-tightening	---

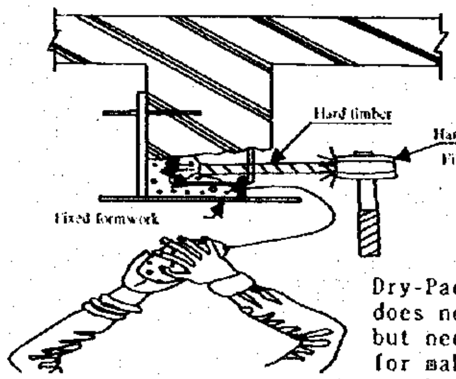
2.2 Major Repair Methods

2.2.1 For Concrete Members

(1) Dry-Pack Method

Applicable Damage: Cracking, Delamination, Honey combs, Wear

The dry-pack method is used in repairing areas such as narrow slots, cone-bolts, she-bolts and grout insert holes which have a depth equal to or greater than the least surface dimension. Dry-pack is usually a mix of one part of cement to three parts of washed plaster-sand (fine sand), by weight.



Dry-Pack material does not dry-up, but need adhesion for make ball like as shown in the drawing

Clean up damaged part
↓
Form work
↓
Fill up the material
↓
Tighting the material
↓
Take care with 7days
↓
Removed form work

Materials: Mortar, concrete

◆ Comments about this method

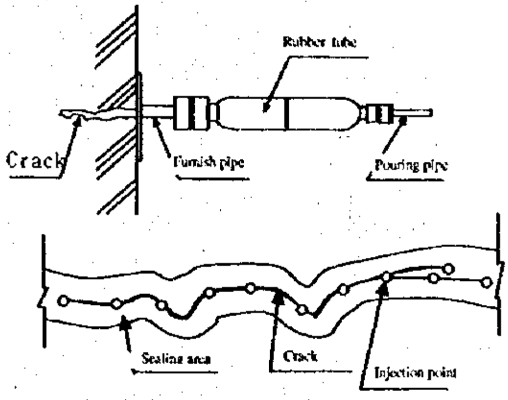
Repair is done by pre-wetting the surface and applying a stiff mortar or bonding grout. The bonding grout mix is one to one (1:1) mix by volume of cement and fine sand mixed to a thick-cream consistency.

The dry-pack mix should be promptly compacted into place before the bonding grout dries. The dry-packed mix is compacted with a variety of wooden tools, the exact choice of which should be made by the user to best fit the job requirement. Wooden tools are preferred, as they don't polish the surface layer of the mix and consequently offer better bond between each successive layer of the dry-pack.

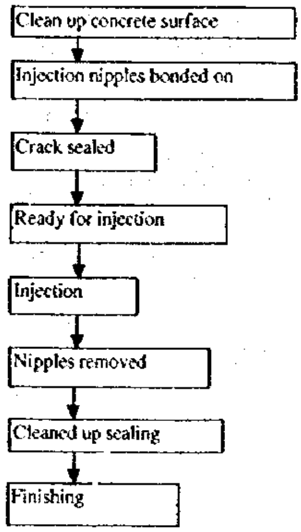
(2) Injection Method

Applicable Damage: Cracking

In reinforced concrete, cracks wider than about 0.3 to 0.4mm should be sealed and filled by injection. Before deciding the most appropriate method/material for repairing/sealing a crack, a determination should be attempted on its cause and whether it is active or dormant. Whether the crack is active, may be determined by periodic observation. A crack resulting from a rare load-application, and which has ceased to propagate, can be repaired (if it is wider than about 0.3 to 0.4mm) by pressure-injection with suitable epoxy-formulation so that the integrity is restored and any adverse influence on the service life of the structure is eliminated or minimized.



First, clean up concrete,
then sealing the crack.
Put on furnish pipe
Epoxy/polymer resin injection



Materials: Flexible or rigid epoxy filler

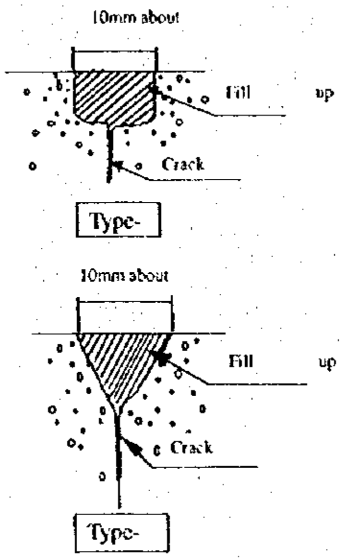
- Comments about this method

Dormant cracks, in excess of about 0.3 to 0.4mm width, must be cleaned and then filled and sealed, by epoxy-injection for widths up to about 1mm, and fine cement grout for wider cracks. Where live crack width exceeds about 0.3 to 0.4mm, "V-groove" should be made along the crack, the groove and the cracks cleaned by a dry air-jet, and then filled to parts of its depth by a flexible filler to prevent ingress of moisture and other deleterious materials. After the crack has become dormant, the filler can be removed and the crack cleaned and filled with a rigid (epoxy) filler.

(3) Caulking Method

Applicable Damage: Cracking

Caulking method is used for cracks wider than about 0.5mm. Cutting the concrete along the cracks, and then fill the materials which are Elastomeric sealer for seal it, and are cement grout or mortar, fast-setting mortar for dormant cracks.



Clean up surface
↓
Cut with saw or chipping tools
↓
Clean up cutted surface
↓
Bond painting
↓
Fill up material
↓
Sheeling and finishing

Materials: Elastomeric sealer, cement grout, cement mortar, fast setting mortar

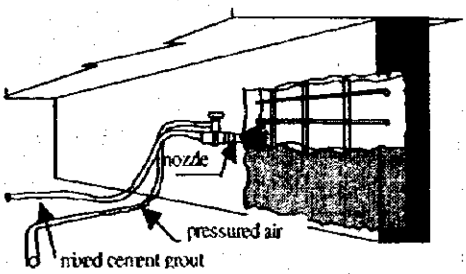
◆ Comments about this method

In case of non-corroded reinforcing bar, after cut the concrete with figure "V" or "U" type, and then filled the materials. "U" type, after cut the concrete at both side of the cracks, then should have chipping off among area. "V" type is easily to cut the concrete although, but also easy to take off the filled materials. So recommend to use "U" type. In case of corroded reinforcing bar, should take off the rust in the first place. There are many cases to be rusted expand around, so must be repaired including such area.

(4) Shotcrete/Gunite

Applicable Damage: Cracking, Scaling/Spalling, Delamination, Efflorescence, Honey combs

Shotcrete (pneumatically applied cement-concrete) and Gunite (pneumatically applied cement-mortar) are suitable for forming the new concrete (i.e. the restoration-concrete) and for strengthening and jacketing of various structural elements.



Except deteriorated concrete
↓
Clean up concrete surface
↓ ← Cement Mortar Mix
Spread mixed cement

Materials: Shotcrete/Gunite, cement concrete, cement mortar.

◆ Comments about this method

Pre-treatment of the exposed concrete surface is of prime importance when using shotcrete or gunite. Sand blasting has proved to be an efficient surface treatment procedure. The exposed sound concrete surface should be sufficiently pre-moistened. No bonding agent is necessary because at the interface a mortar enrichment occurs as result of aggregate rebound.

Shotcreting in multiple layers requires that the preceding layer achieves a sufficient degree of hardness prior to shooting-on the next layer. Some nominal reinforcement may be required for a thickness larger than 50mm. This reinforcement should be fixed in position in such a manner that it remains stiff and keeps its position during shotcreting operations (chicken wire mesh is handy).

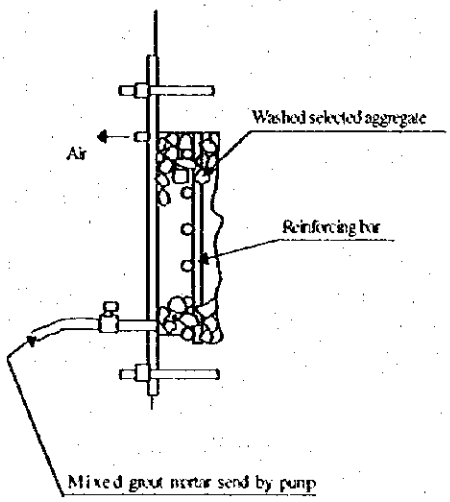
Curing may be accomplished by an evaporation protection method (e.g. plastic sheet cover), to prevent a rapid drying out. If a freeze-thaw/salt resistant concrete is required, air entrainment admixture may have to be added to the mix. Also, surface protection measures may be necessary in certain cases. There are two basic gunite or shotcrete processes:

-- a "dry mix" process, where the mixing water is added at the nozzle to which the cement-stand mixture is brought by compressed air through the delivery hose.
-- a "wet mix" process where all the ingredients, including water, are mixed before entering the delivery hose.

(5) Pre-pack Method

Applicable Damage: Scaling/Spalling, Delamination, Efflorescence, Honey combs, Wear.

Pre-pack (or Pre-placed Aggregate) method is used most advantageously on large repair jobs, especially where placement of normal concrete would be difficult.



1. Except deteriorated concrete
2. Install reinforcing bar
3. Install form work
4. Fill up washed selected aggregate
5. Setting Nipples and bottom of form work
6. Mortar mix →
7. Sent mixed mortar by pump

Materials: Coarse aggregate, cement grout.

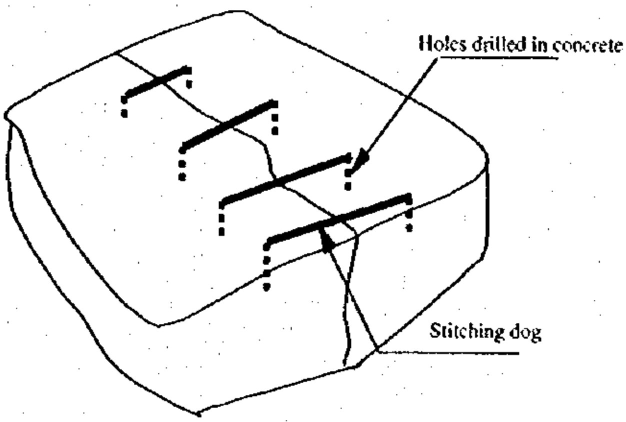
◆ Comments about this method

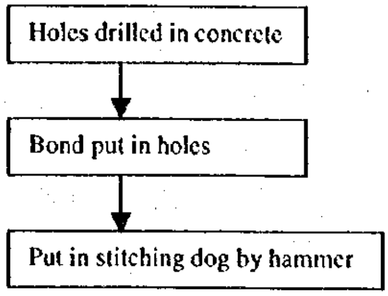
The process consists of removal of deteriorated concrete using pneumatic hand hammers. Then the cracks are grouted and dowel bars are anchored into the sound concrete to fasten the temperature and shrinkage reinforcement bars (generally 10mm dia. @ 150mm centres, in two orthogonal directions). A form is placed around the perimeter of the repairs, then clean coarse-grade aggregate (minimum 16mm size for thick sections, and minimum 12mm size for thin sections) is placed and compacted before pumping a especially designed cement sand grout into the aggregate by especial insert fitting placed in the face of the forms. The coarse aggregate may be of any suitable size, depending on the thickness of the repairs. Normal size varies from 20 to 40mm down.

The preplaced-aggregate concrete offers low drying shrinkage because of its point to point contact between coarse aggregate and high bonding strength, which are essential properties for all concrete repairs.

(6) Stitching Method

Applicable Damage: Cracking.





Materials: Steel pins.

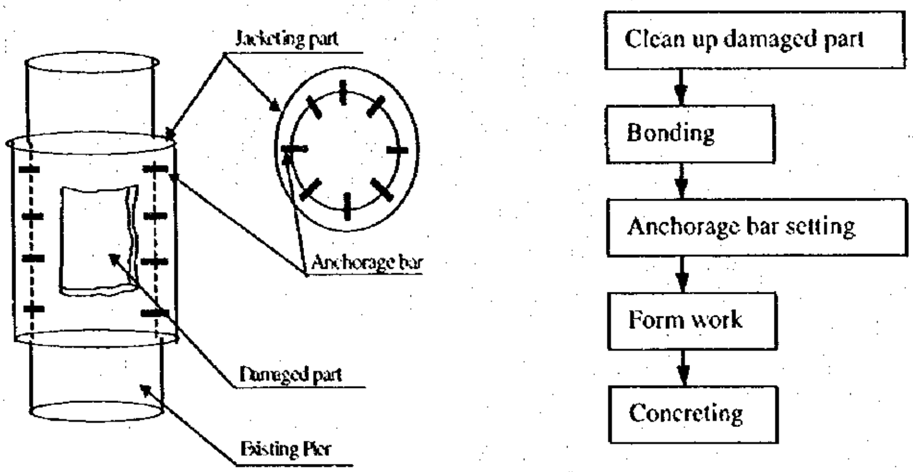
- Comments about this method

Stitching "across" the cracks in reinforced concrete members is done either along the cracks or as a series of bands around the members. Reinforcement is placed across the cracks in suitable grooves which are suitably gunited or shotcreted. Steel pins (dogs) are also used to stitch across the cracks

(7) Jacketing Methods

Applicable Damage: Cracking.

Jacketing method involves fastening of external material over the concrete members to provide the required performance characteristics and restoring the structural value.



Materials: Cement mortar, anchorage bar, fiber-glass, reinforced plastics, ferrocement, and polypropylene can also be used for jacketing.

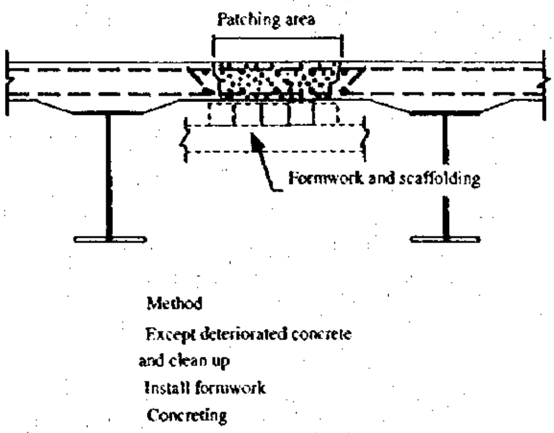
◆ Comments about this method

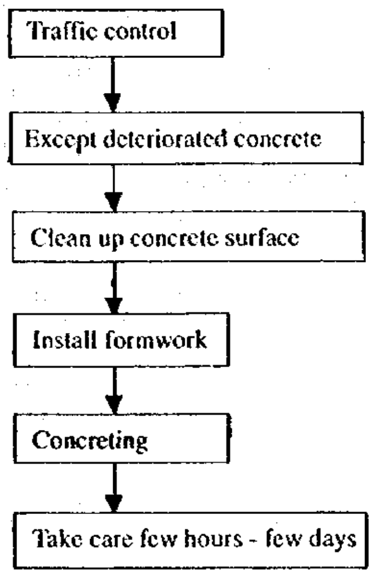
The jacketing materials are secured to concrete by means of bolts and adhesives or by bonding with existing concrete. Fiber-glass reinforced plastics, ferrocement, and polypropylene can also be used for jacketing.

(8) Patching

Applicable Damage: Cracking, Scaling/Spalling, Delamination, Efflorescence, Honey combs.

This is a kind of "Partial or Full-Depth Concrete Replacement" method and for repairing patches, breakage in concrete.





Materials: Cement mortar, epoxy concrete.

◆ Comments about this method

To remove all unsound concrete, install the formwork and concreting.
Removal of unsound concrete can be accomplished by:

- -- mechanical methods
- -- thermal methods
- -- chemical methods

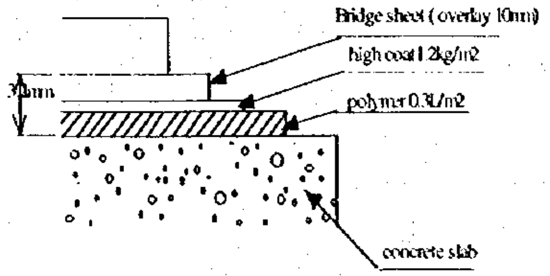
As for the mechanical methods, the usual ones are:

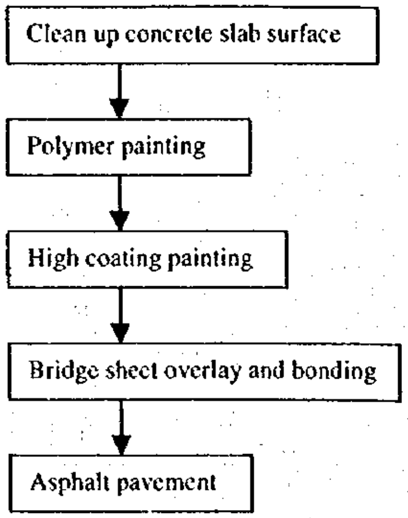
- -- chipping method
- -- milling method
- -- sand-blasting method
- -- very high pressure water-jetting method
- -- steam-blasting method

(9) Coating Method

Applicable Damage: Cracking, Scaling/Spalling, Efflorescence.

This is a kind of water-Proofing "membrane" system(for preventing moisture ingress). The bituminous wearing surface with "membrane" has been used widely in Europe and the north eastern United States, and its performance has been acceptable.





Materials: Bituminous coating, tar, asphalt concrete.

◆ Comments about this method

The advantages of a membrane are its easy installation and its relatively low cost. The advantages are as follows:

1. Premature deterioration of bituminous overlay in area of high volume traffic and inadequate drainage.
2. Blistering, caused by expansion of trapped air and water vapor after placement.
3. Poor bonding at the protection layers in the area near the expansion joint.
4. Local instabilities due to bleeding and bubbling.
5. Replacement of the membrane whenever the surface is removed.

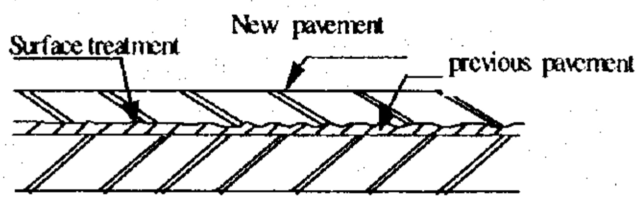
It is suggested that the minimum thickness of asphalt wearing surface over the membrane be a minimum of 65 to 80mm., if placed in two coarse, the lower coarse should be denser or more impermeable than the upper coarse in order to prevent trapping of water in the low coarse.

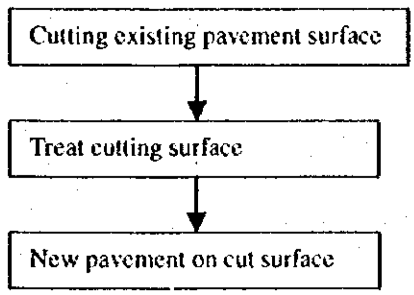
(10) Overlaying

Applicable Damage: Cracking, Scaling/Spalling, Efflorescence, Wear.

The protective system should be effective, durable and reasonably economical. If the system is water-proof and keeps chloride out of the deck or prevents corrosion of reinforcement, it is considered to be effective. If the system provides effective protection for 5 to 10 years under moderate service conditions, it may be considered durable. The following are the currently recommended alternate overlay protective systems.

1. Low-slump highly dense concrete
2. Latex-modified concrete
3. Water-proofing membrane system
4. Polymer-Impregnation of Concrete and Polymer Concrete Overlay
5. Protective Sealer





Materials: Membrane, asphalt with membrane.

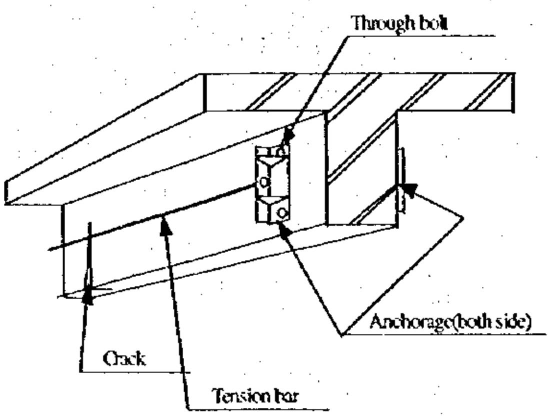
◆ Comments about this method

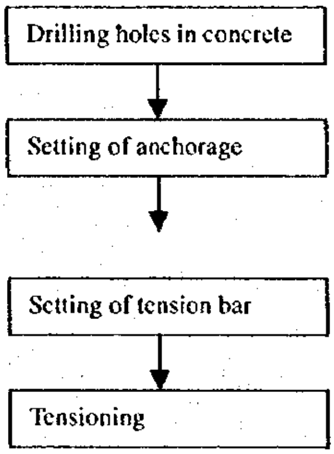
A concrete overlay system requires a minimum of 6mm scarification over the entire deck slab, and each system requires removal of all delaminated and deteriorated concrete to the scarifying level. Membranes and overlay systems, installed on the concrete deck slabs subject to de-icing salts, have shown good performance of retarding active corrosion and sealing of corrosion-attributing moistures and oxygen. However, removal of contaminated concrete will give better results.

(11) External Prestressing

Applicable Damage: Cracking.

Repair by arresting crack-propagation by the post-tensioning principle.





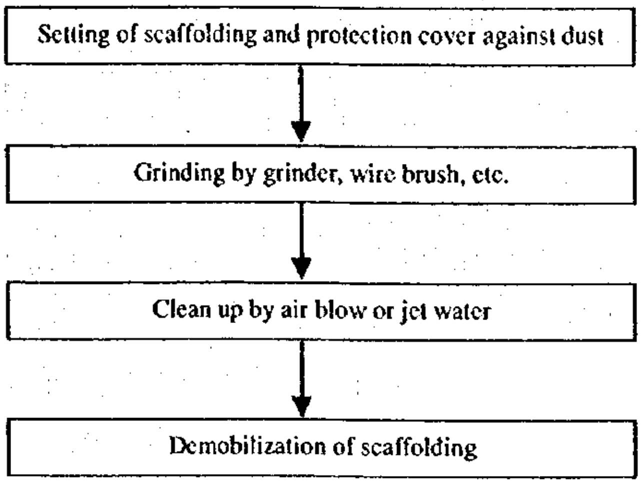
Materials: Steel plates, post-tensioning reinforcement bar, steel pins.

◆ Comments about this method

The flexural cracks in reinforced concrete can be arrested and even corrected by the post-tensioning method. It closes the cracks by providing compression force to compensate for tension and adds a residual compression force. This method requires anchorage of the tie-rods (or wires) to the anchoring devices (the guide-bracket-angles) attached to the beam. The rods or wire are then tensioned by tightening the end-nuts or by turning of turnbuckles in the rods against the anchoring devices. However, it may become necessary in certain critical cases to run at least an approximate stress-check to guard any possible adverse effects

(12) Grinding

Applicable Damage: Scaling,/Spalling, Efflorescence.



Materials and Equipment: Grinder, wire brush, Air compressor.

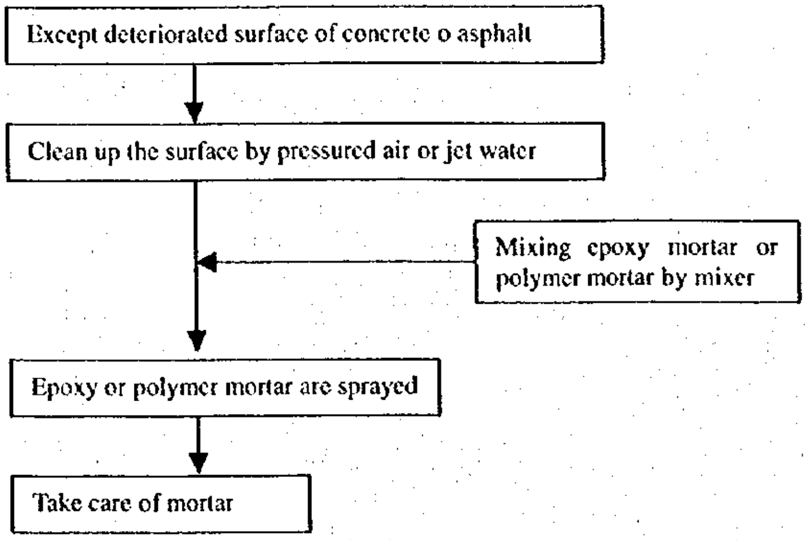
- Comments about this method

This is a one of the most economical cleaning on concrete surface. Not effective for any superficial damage of the concrete.

(13) Re-surfacing

Applicable Damage: Efflorescence, Delamination, Honey combs, Wear

There are plenty of re-surfacing method, here-in after, describing about Polymer Concrete Over Lay.
A polymer concrete over lay protective system has been used as an experimental project in several states in the US.



Materials: Epoxy concrete, polymer concrete

- Comments about this method

The overlay consists of an application of monomer resin to the deck surface, followed by an application of the fine aggregate.

The process is repeated until four layers have been placed. The over lay is relatively impermeable and skid resistant. Generally, the resin is sprayed over the deck and fine aggregate is covered over the resin. After polymerization, the excessive aggregate is removed and the process is repeated for other layers. The four layers produce a thickness of about 12 to 15mm. The overlay system consists of the following steps for each layers.

1. surface preparation
2. mixing and application of monomer resin
3. fine aggregate application and compaction
4. polymerization of monomer and removal of excess aggregate

2.2.2 For Steel Members

(1) Corrosion

◆ Origin and causes

Corrosion damage will occur more or less on all kinds of steel in bridges and will increase with time. Beam, girder, or floor beam top flanges in contact with or encased by deteriorated or chloride-contaminated concrete create a suitable environment for steel corrosion loss. The entire beam section at joint locations may undergo severe corrosion loss caused by leakage and intrusion of salt-laden runoff water.

◆ Repair procedures

In the usual case, a paint application will provide corrosion protection while enhancing also the appearance of the structure. Initial cost, method of application, and durability are factors determining the choice. The repair work consists of surface preparation, prime coating, and finish coating. Appropriate manuals and special provisions usually outline the details including materials, cleaning, preparation, and application.

① Cleaning

Mechanical or solvent cleaning is indicated for essentially sound coated surfaces where scraping or wire brushing can remove loose paint and a solvent can remove oil or grease residue. For small degraded or corroded areas, a combination of mechanical cleaning and dry blast cleaning will accomplish the intended preparation. Commercial blast cleaning consists of a wet or dry blast cleaning of the entire metal surface with the intent to remove all the previous coating and any loose or poorly bonded mill scale and corrosion. Finally, a near-white blast cleaning is a multipass process that removes all previous coating, corrosion, and mill scale to expose bare metal.

② Prime and Finish Coating

The prime coating may be either an organic or inorganic zinc, an epoxy mastic, or an coal tar epoxy. Zinc coatings require a near-white or commercial blast clean surface. Organic zinc coatings ensure good adherence to the surface and usually require top coats. Inorganic zinc coatings create a chemical bond with the steel surface, and provide good protection without the need for a top coat when applied to a dry film thickness of about 4 mils. Epoxy mastics and coal tar epoxy prime coats should be applied over a sound previously coated surface. Coal tar epoxy coatings may also be used on bare metal.

Finish coatings may be vinyl, epoxy, latex, acrylic, urethane, or alkyd. These coatings may attain various degrees of gloss, and are available in a variety of colors. They should be applied as directed by the manufacturers or suppliers.

③ Procedure for Repairing Corroded Steel Beam

The beam is replaced by cutting out the damaged portion and replacing it with a new shape section or built-up plate section. All beams must be lifted simultaneously whether they are to be replaced or not. The construction procedure involves the following steps.

1. Relieve the load at the bearings by jacking under the sound portion of the beams.
2. Cut out the corroded section.
3. Weld the new section into place using full penetrating welds. The new section may be either a suitable shape section or be shop-fabricated from other suitable shapes.
4. Lower the span to bear and check for any distress.
5. Remove jacking equipment and other temporary supports.

(2) Repair of Fatigue Damage

Fatigue should be considered a potential problem. Older bridges were initially designed for lighter vehicles under specifications without fatigue provisions. These bridges may now have members and details characterized as fatigue-critical and subject to high stress ranges under heavy trucks. Furthermore, early repair procedures utilized welding and related techniques without consideration of fatigue effects. Whereas welding was often done to expedite prompt repair work, in some instances it has resulted in shorter fatigue life for the bridge.

The fatigue life of a given detail is related to the number of cycles of loading that can be sustained before fatigue. This is determined by the range of stress to which the detail is subjected during loading. It appears from this brief comment that the fatigue strength of a member or detail is governed by the live load stresses, and determining the live-load stress range is essential for assessing the fatigue life of the member. On the other hand, if the strength of the member is controlled by dead load stresses, fatigue provisions are unlikely to govern.

Thus, the concept of safety applied in fatigue design is markedly different from the concept applied in most static strength designs, usually based on the worst conditions expected to occur during the service life of the bridge. Fatigue design, by contrast, is based on typical conditions occurring frequently, because many repetitive applications are necessary to cause failure. In fatigue designs, permissible stress conditions are related to particular design lives, and exceeding these permissible conditions merely shortens the service life rather than causing immediate failure.

(3) Impact Damage

Rolled beams and plate girders in superstructures are sometimes damaged from over-height vehicles attempting to go under the bridge. This damage is often so severe that traffic on the bridge must be restricted or the bridge may have to be closed until the damage is repaired. On structures over streams the same type of impact damage can occur by moving ice or debris during periods of flood. On through girder bridges, the top flange, web stiffeners, and knee braces are also subject to damage from roadway traffic.

Any crack or fracture in a steel beam should be considered a sign of serious distress, and should be approached with immediate corrective action. Very often by the time a crack is visible, the member may be close to failure.

Repair of collision damage, whether caused by traffic or ice and debris, is often very difficult and may involve beam replacement in extreme cases. If no tear or crack apparent and minor, it can be repaired by flame straightening mechanical straightening. Minor nicks and gouges due to accidents should not be allowed to remain, because they can raise stresses locally and often propagate cracks.

(4) Flame Straightening Beam or Girder

◆ Usual Damage

The most common vehicle-caused damage to girders and beams is manifested as a lateral bend of the bottom flange accompanied by angular rotation, rarely occurring, however, if the girder is composite with the slab. If the web has been impacted, there may be an indentation. Diaphragms and bottom lateral bracing may also suffer damage in the form of bends.

◆ Supplementary Girder Supports

During the flame straightening process, the girder strength is temporarily degraded due to heating, and as a result live load should not be applied on the girder during heating and cooling. If the dead load stress is significant, vertical jacking may be necessary to reduce this stress to inconsequential values.

◆ The Straightening Process

Straightening is usually implemented in the reverse sequence that took place when the damage occurred. It should begin with components away from the point of impact, such as diaphragms and lateral bracing. When these components are bent beyond the elastic limit, a partial straightening should be first introduced to permit girder straightening. Secondary members may be restored by flame, hot or mechanical straightening, or combination thereof. However, flame straightening is recommended because it dose not cause steel degradation. The flame straightening process for secondary members is as in primary components. However, because of the different shapes involved and their orientations, the heat pattern may be different.

2.2.3 For Timber Members

Accidental or normal damage in timber bridge may take the form of shattered, splintered, or deformed timber, large longitudinal cracks, or sagging and buckled members. This damage is normally caused by collision and over-loading. Damage due to fire is usually complete and the only option is total replacement. The presence of bituminous surfacing can complicate the inspection of timber decks following accidental damage. In these cases the bituminous surface should be removed in selected area, and special attention should focus on the condition of the deck soffit. Repair procedures may be confined to the repair of cracked or split timber members or they may involve complete member displacement.

2.2.4 For Foundation

(1) Scour

Rip-rap is a typical repair procedure for pier footings supported on pile foundations undermined by scour. A concrete sub-footing that envelopes the original footing provides complete protection to the footing and the piles and restores the structural interaction with the soil system. This repair can be accomplished in stages involving the construction of a cofferdam around the pier, pumping out the water, and installing forms for the sub-footing. The concrete is poured in the dry and vibrated to fill the space completely. Stone rip-rap is usually placed after the cofferdam is removed, and functions as protection for the new foundation. Where possible, the rip-rap should not extend above the original stream-bed because it may act an obstruction to the stream flow.

(2) Settlement

Foundations commonly load the soil underneath. Elastic deformation occurs quickly and is usually small so that it may be neglected in the design. Volumetric changes associated with reduction in the water content of the subsoil(usually referred to as consolidation) can be estimated and measured. Consolidation settlement occurs in all soils. In cohesionless soils the consolidation process is quick and is normally not distinguishable settlement. In cohesive soils consolidation can be a long process. Various loads can have significant effects on the magnitude of settlement or lateral displacement of a soil. Among the factors influencing this process are: (1) the ratio of sustained load to total load; (2) the duration of sustained loads; and (3) the time interval over which settlement or lateral displacement occur. Consolidation settlement in cohesive soils are time-dependent, so that transient loads have negligible effect. In cohesionless soils, however, and where the permeability is high, elastic deformation of the subsoil due to transient loads can occur rapidly. Since deformation in cohesionless soils also takes place during construction as the loads are applied, part of the overall settlement can be accommodated by the structure to an extent compatible with the construction method. In the same context, settlement due to transient loads may be significant in cohesionless soils. In case of small settlement, there is a repair method that additional structure put on the substructure, and then adjust the road level. If intend to remake sufficiently, it may be considered being replacement.

References:

1) "Bridge Inspection Manual" issued by Ministry of Construction of Japan

2) "Bridge Strengthening and Rehabilitation" 1996 by Prentice Hall PTR Prentice-Hall, Inc. A Simon & Schuster Company Upper Saddle River, New Jersey 07458.

3) "Bridge Inspector's Training Manual/90, July 1991, July 1991 issued by U.S. Department of Transportation. Federal Highway Administration.

DIVISION IV

BRIDGE DESIGN

DIVISION IV BRIDGE DESIGN

CONTENTS

DIVISION IV BRIDGE DESIGN

CHAPTER 1 GENERAL

1.1 Scope

A whole bridge structure consists of a superstructure and a substructure, and the substructure is categorized into a body portion and a foundation portion.

The scope of the Manual shall limit only to use for short- and medium- span bridges in rural areas, which corresponds with the purpose of the Project. Thus the structures described hereinafter in the Manual of Bridge Design are shown below;

(1) Superstructure

1) Prestressed Concrete Girder with Concrete Deck
   Pre-tentioned Girder
   Post-tentioned Girder

2) Steel Girder with Concrete Deck
   Composite Rolled Beam
   Composite Plate Girder

(2) Substructure

1) Reinforced Concrete Abutment, Reinforced Concrete Pier,
2) Reinforced Concrete Spread Footing

1.2 Specifications

For many years, the basic manual for design of highway bridges has been the *Standard Specifications for Highway Bridges* adopted by the American Association of States Highway and Transportation Officials (AASHTO).

The latest version of the specifications at the time of the preparation of this Manual is that in the year of 1994.
The specifications permit use of either allowable stress design or load factor design.
Here only the allowable stress design is adopted, for it has been conventionally used in Chile.

The sections of the Specifications in close relation with the Manual are;

SECTION 1	DESIGN ANALYSIS AND GENERAL STRUCTURAL INTEGRITY FOR BRIDGES
SECTION 2	GENERAL FEATURES OF DESIN
SECTION 3	LOADS
SECTION 4	FOUNDATIONS
SECTION 7	SUBSTRUCTURES
SECTION 8	REINFORCED CONCRETE
SECTION 9	PRESTRESSED CONCRETE
SECTION 10	STRUCTURAL STEEL

1.3 Selection of Materials and Types for Superstructure

The type of superstructure chosen for a bridge can be based on a variety of factors ranging from maintenance considerations to personal preference. Specially some of the commonly used criteria in selecting the type of superstructure to be used are;

- Material function and availability
- Speed of construction
- Design complexity
- Maintainability
- Environmental concerns
- Total cost

Where there are no steadfast rules governing which of the factors listed above is more important than the other, one certainly is that the use of superstructure types varies geographically.

Superstructures generally vary by support type (simply supported or continuous), design type (slab-on-stringer, arch, rigid frame, etc.), and material type (steel, concrete, timber, etc.).

For the primary superstructure members of a bridge, concrete (reinforced and prestressed) and structural steel are the principal candidates. Although there remain still many timber bridges in Chile, timber is expensive compared with other materials nowadays and furthermore it is not desirable from a viewpoint of conservation of environment, and thus the Government of Chile decided not to use the timber material for a new bridge. Concrete and steel have desirable attributes and shortcomings as bridge materials.

In general, bridges of concrete and steel can be designed, constructed and maintained to ensure long life. On the other hand, timber bridge has a rather shorter life but is easy in construction and maintenance.

Some advantages of concrete bridges are:

- They do not require painting.
- They do not rust (but are susceptible to rebar corrosion).
- They can be formed to the desired shape (if of reinforced concrete).
- If of prestressed concrete, they may be fabricated more quickly than steel, although in some emergencies steel replacement structures have been fabricated and erected as quickly as prestressed members.
- They are not susceptible to fatigue failure.

Some advantages of steel bridges are:

- Lighter weight permits smaller cranes for erection.
- Lighter weight permits reduction of substructure size, number of piles, etc.
- They are more readily dismantled and reused at the same or another site.
- Use of conventional erection and construction techniques may avoid construction cost overruns and litigation sometimes experienced with segmental concrete.
- Attachments to bridge are readily made by bolting or welding.
- Components are accessible and visible for inspection.
- Members damaged by vehicular collision may be more easily repaired than concrete members.

For short- to medium-span bridges, the selection of material will depend on which bridge type and material is the most economical for the particular site. This may be known by the experience with bids received over a period of time, or can be determined by taking alternative bids on projects.

1.4 Seismic Design

(1) General

In regions where earthquakes may be anticipated, structures shall be designed to resist earthquake motions by considering the relationship of the site to active faults, the seismic response characteristics of the total structure in accordance with the provisions of Seismic Design of AASHTO.

The design earthquake motions and forces specified in these provisions are based on a low probability of their being exceeded during the normal life expectancy of a bridge. Bridges and their components that are designed to resist these forces and that are constructed in accordance with the design details contained in the provisions may suffer damage, but should have low probability of collapse due to seismically induced ground shaking.

The principles used for the development of the provisions are:

1) Small to moderate earthquakes should be resisted within the elastic range of the structural components without significant damage.

2) Realistic seismic ground motion intensities and forces are used in the design procedure.

3) Exposure to shaking from large earthquakes should not cause collapse of all or part of the bridge. Where possible, damage that does occur should be readily detectable and accessible for inspection and repair.

(2) Applicability of Standards

These Standards are for the design and construction of new bridges to resist the effect of earthquake motions. The provisions apply to bridges of conventional steel and concrete girder and box girder construction with spans not exceeding 150 meters. Suspension bridges, cable-stayed bridges, arch type and movable bridges are not covered by these Standards.

The provisions specified in these Standards are minimum requirements.

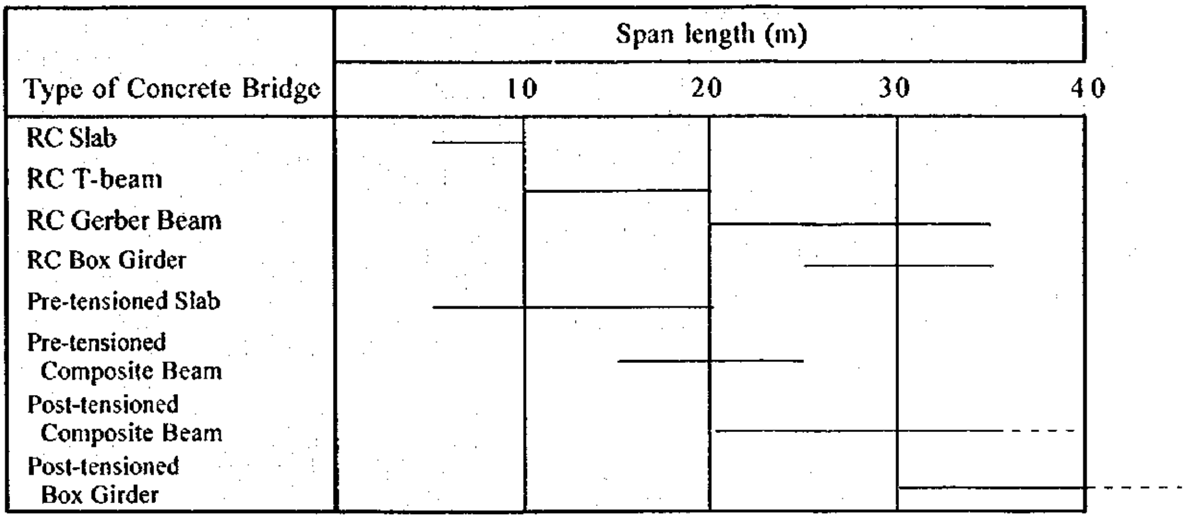
CHAPTER 2 CONCRETE BRIDGES

2.1 General

(1) Type of Concrete Bridge

The major advantages in the use of concrete for bridge are economy in short and medium spans, durability, low maintenance costs and easy adaptability to make shape. The principal types of cast-in-place bridges are the longitudinally reinforced slab, T-beam or girder, and cellular or box girder. Precast construction, usually prestressed concrete bridges of I-beam, T-beam or box-girder cross section. The range in span of various concrete bridge types is given in Table 4.1 .

Table 4.1 Type of Concrete Bridge and Span Length



(2) Prestressed Concrete Bridge

The normal design procedure for precast/prestressed concrete beams are to design for allowable working stresses and to check initial stresses and ultimate moment capacity. Most designs for this type of section utilize pretensioned prestressing in which the strands are stressed before the concrete is placed around the strands. When the concrete has cured to sufficient strength the strands are cut and the prestressing is transferred to the beams. Some post-tensioning is used on occasion with precast sections. The ducts are cast in the section and strands are installed after concrete placement and curing. After the concrete cures the strands are jacked, anchored, and grouted.

For precast/prestressed concrete beams, concrete strength of 350~420 kg/cm^2 are used. Strengths at transfer of prestress usually range from 280 to 350 kg/cm^2; 1/2 in. diameter seven-wire, 270K strand is commonly used as the major prestressing.

2.2 General Features of Design

(1) Load Distribution

Analysis for "shallow superstructures", i.e., the solid slab, voided slab, and slab-on-girder type in Europe and Japan is to be highly analytical and usually computer-based. Such methods are the grillage analysis, the orthotropic plate method, and the finite element method. For prestressed concrete "shallow structure", Guyon-Massonnet method which is based upon the orthotropic plate method has been used in Japan since 1955.

On the other hand, the AASHTO method of analysis is simplified method for obtaining longitudinal moments and shears due to live loads which has been in use in North America for many years.

According to this method, a longitudinal girder, or a strip of unit width in the case of slabs, is isolated from the rest of the structure and treated as a one-dimensional beam. The beam is subjected to loads comprising one line of wheels of the design vehicle multiplied by a load fraction *S/D*. *S* is the girder spacing in the case of slab-on-girder bridges, or 1 unit width in the case of slab bridges; and *D*, which has the units of length, is specified to have a certain value according to the bridge type. Values of *D* for various slab-on-girder bridges, as given in the AASHTO specifications.

(2) Safety Provisions of the ACI Code

The safety provisions of the ACI Code are that the load factor γ and the strength reduction factors given an overall safety factor based on load types such that

$$SF = \frac{\gamma_1 D + \gamma_2 L}{\Phi (D + L)}$$

where Φ is the strength reduction factor, and γ_1 and γ_2 are the respective load factors for the dead load D and the line load L. The nominal strength is reduced using a strength reduction factor Φ to account for in accuracies in construction, such as in the dimensions or position of reinforcement or variations in properties.

- Load factor (γ)
  $\gamma_1 = 1.4 \quad \gamma_2 = 1.7$
- Strength reduction factor (Φ)

	For flexure	For shear and torsion
Reinforced concrete beams	0.9	0.85
Pre-tensioned beams	1.0	0.90
Post-tensioned beams	0.95	0.90

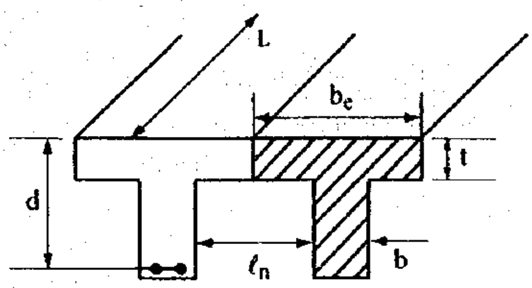
(3) Effective Flange Width

Although it is assumed that the stress is uniform across the entire flange width, the stress actually decreases at great distance from the web. Therefore, the AASHTO code limits top flange width of the composite section. The effective width be has to be modified to account for the difference in the modulus of the topping concrete and precast concrete.

$$bm = \frac{Ect}{Ec}(be) = nb$$

where Ect = modulus of the topping concrete

Ec = modulus of the precast concrete



$$be \leq \min \begin{cases} \frac{1}{4}L \\ b + 12t \\ b + \ell n \end{cases}$$

(4) Bending Moment in Bridge Deck Slab

For many years the design of bridge decks has been done using empirical relationships given in the AASHTO Specification. Relationships which are based upon the work of H.M. Westergaard, are given for slabs which have their main span perpendicular to the direction of traffic as well as for slabs which have their main spans parallel to the direction of traffic.

(5) Loss of Prestress

The reduction of the prestressing force can be grouped into two categories:

- Immediate elastic loss during construction process, including elastic shortening of the concrete, anchorage losses, and frictional losses.

- Time-dependent losses such as creep, shrinkage, and steel relaxation, all of which are determinable at the service-load limit state of stress in the prestressed concrete beams.

The above mentioned prestress losses except anchorage losses are covered in AASHTO specification.

Anchorage Losses

Anchorage losses occur in post-tensioned beams due to seating of wedges in the anchors when the jacking force is transferred to the anchorage. Generally, the magnitude of anchorage-seating loss range between 6.5 m/m, 10.0 m/m. If ΔL is the magnitude of the slip, L is the tendon length, and Es is the modulus of the prestressing wires, the stress loss is easily calculated from

$$\Delta s = \frac{\Delta L}{L} Es$$

Lump-sum estimates of losses

If beam sizes, spans, materials, construction procedure, amount of prestress force, and environmental conditions are ordinary, such as short-medium-simple span beams, it is proper to use the lump-sum estimate of losses which is provided in AASHTO Specification. It should be noted that losses due to friction are not included in the values for post-tensioned beams.

2.3 Design of Composite Beams

(1) Beam Cross Section

The simple short-span girder requires a relatively thick web because of shear stresses. A large bottom flange is required to store the prestressing force and the size of the top flange of short-span bridge beam is relatively small as modified I-shaped cross sections. For beams of long span, flexure is the primary design consideration. Because the bulk of the moment is due to dead loads, most which may be acting at the time of prestressing, a large bottom flange is not required. A substantial top flange is needed as T-beam cross sections.

Further consideration of the above present that precast prestressed girders of optimum design will have different shapes for different spans. Generally speaking, I, T, and box sections with relatively thin webs and flanges are more efficient cross sections. Different shape of cross section for the standard bridges are used in U.S.A., UK and Japan.
In UK, pre-tensioned the inverted T-beams or M-beams, and post-tensioned U or Box-beam have

been used as the standard bridges. Exact T-shaped beams are currently used as the standard bridges in Japan from viewpoint of easy construction.

The cross sections of standard bridges in Chile are I or T-shaped beams with similar to the AASHTO standard beams (type I ~ type VI).

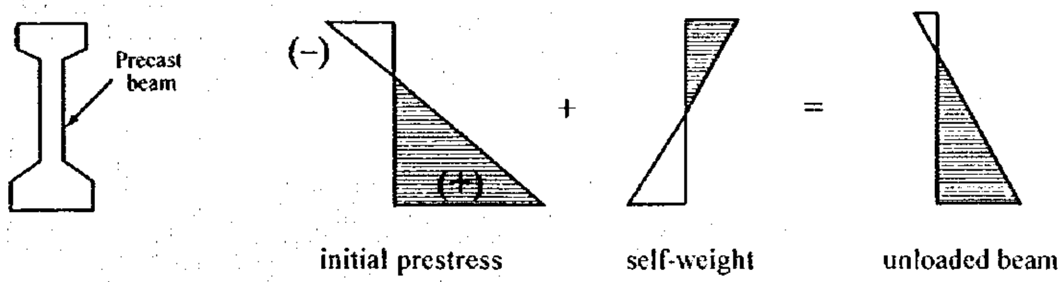
(2) Concrete Stress Distribution

The girders and the floor slab are connected by shear connectors by which they are combined to work solidly together.

In a prestressed concrete composite girder bridge, because the stress distribution in the same section changes depending on construction sequence and process, the stress in the respective construction stages before and after the composition must be calculated to obtain the combined stress for the respective section. The concrete stress distribution due to composite action are shown in Fig. 4.1. Concrete stress due to stress by difference of creep and shrinkage of concrete is not severe effect, because the top and bottom of beam are compression and tensile zone respectively, in the simply supported beam.

(a) unloaded beam, with initial prestress plus self-weigh

(+) = compression (–) = tension



(b) loaded beam, with effective stress, self-weight and full service load

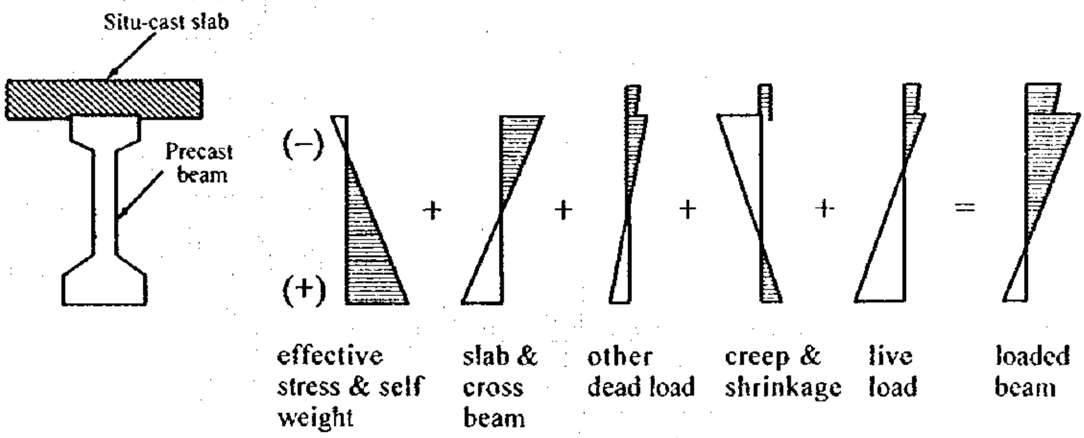


Fig. 4.1 Concrete Stress Distribution

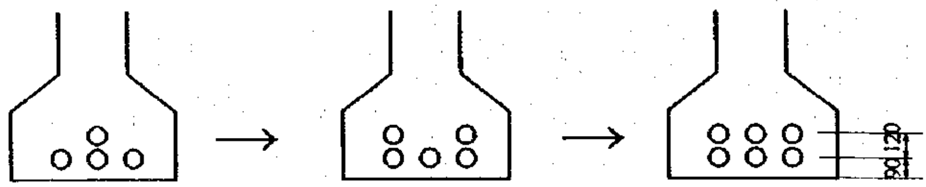
(3) General Guideline for Structural Details

(a) Main Beam

- The height of beam-to-span ratio normally employed in beam range from 1/15 to 1/20
- Spacing of beam is to be less than 3.0 m
- The thickness of web is to be 18 to 20 cm
- Change in web thickness shall be tapered for a minimum distance of 5 times the difference in web thickness
- The distance between the end of beam and support

  300 mm for 14 ~ 24 m of span length

  400 mm for 24 ~ 36 m of span length
- Basic arrangement of tendon cable for post-tensioned beam



N = 4　　　　N = 5　　　　N = 6

(b) Cross Beam

- A cross beam shall be provided at a support of main beams. One or more cross beams shall generally be provided in every span at the interval not exceeding 15 m.

- The minimum thickness of cross beam shall be 25 to 30 cm.

(4) Flow Chart of Flexure Design

Fig. 4.2 shows a flow chart for the flexure design of prestressed beams.

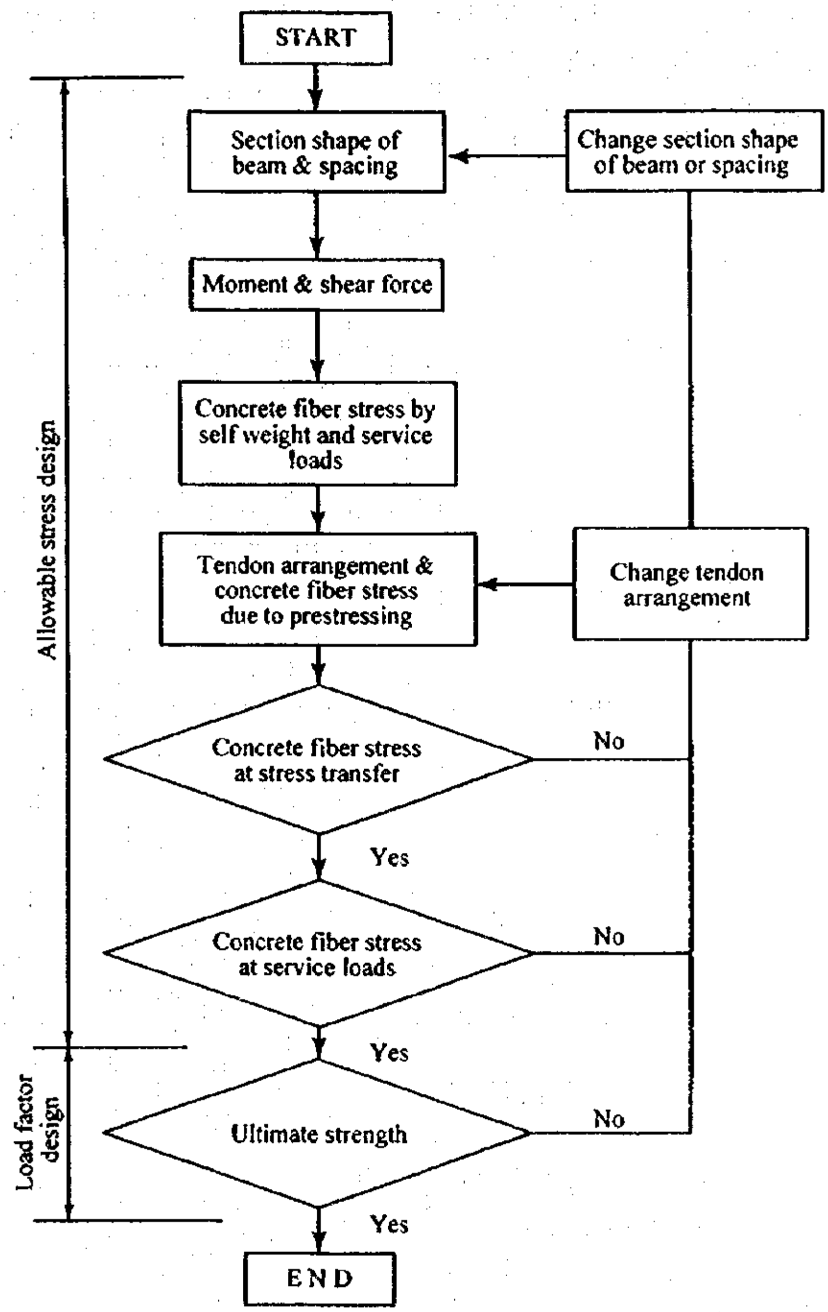


Fig. 4.2 Flow Chart of Flexural Design

2.4 Design of Other Matter of Bridges

(1) Deflection of Beams

When the prestress force is first applied, a beam will normally camber upward. With the passage of time, concrete shrinkage and creep will cause a gradual reduction of prestress force. In spite of this, the upward deflection usually will increase, due to the differential creep, affecting the highly stressed bottom fibers more than the top.

Deflections for uncracked prestressed beams are as follow;

(1) Deflection due to self-weight and service loads

$$\delta \fallingdotseq \frac{5M\ell^2}{48EI}$$

where M = Maximum moment by loading at midspan

(2) Prestressing camber

$$\delta p \fallingdotseq \frac{Mp\,\ell^2}{9EI}$$

where Mp = Maximum moment by prestress at midspan

(3) Deflection due to concrete creep

$\delta c = Cc\,(\delta d + \delta pe)$

where Cc = Creep coefficient
δd = Deflection due to dead loads
δpe = Deflection due to effective prestress

(2) Debonding for Pre-tensioned Beam

Because of the changes in stress induced by the application of loading at different sections along a beam, the optimum use of prestressing requires that the position of the tendons should change within the section from one point to another along the length. In post-tensioning this is achieved without difficulty by fixing the cable ducts to the required profile before concreting. Where pretensioning is used this obviously cannot be done, since the tendon is stressed prior to concreting. The tendon can be pulled or deflected out of a straight line to approximate to the ideal profile but this "harping" adds complexity to the stressing procedure and is only reckoned as appropriate for large units. An alternative technique for simulating the effect of a profile is to break the bond between selected tendons and the surrounding concrete near the ends of the unit. This "debonding" is achieved by placing sleeves over the selected tendons and thus rendering them ineffective at that point. Plastic pipe is usually used for the purpose.

(3) Dapped-end Beam

A dapped-end beam is a structure with reduced depth at its end in order to provide the seating on corbels or gerber hinge portion without loss of clear height between floors.

Two types of cracks can develop, such as direct shear cracks and diagonal tension cracks caused by flexure and axial tension in the extended reduced depth and the stress concentration at the corner.

(1) A corner of a notch of a dapped end has cracks easily due to the stress concentration, therefore it shall generally be provided with a haunch.

(2) At a dapped end, the flexural, shear and diagonal tension reinforcements shall be arranged and anchored with sufficient anchorage length to the portion of no-notch.

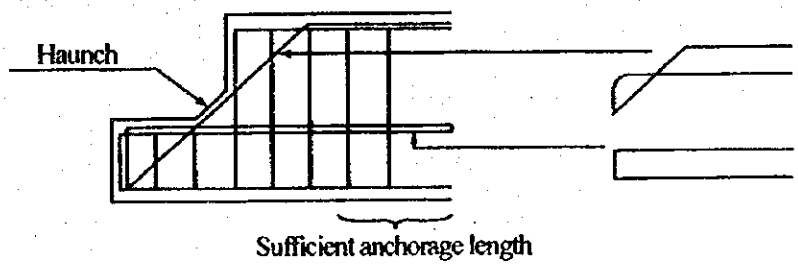


Fig. 4.3 Anchoring reinforcements at dapped end

CHAPTER 3 STEEL BRIDGES

3.1 General

(1) Types and Span Length

There are several types of steel bridges. They are classified into girder bridges, truss bridges, arch bridges, cable stayed girder bridges and suspension bridges. The project aims at a rehabilitation of short- to medium-span bridges, therefore hereinafter girder bridges, or in other words, slab-on-stringer bridges are mainly dealt with.

From a viewpoint of support types, a simply-supported span is probably the most common structural configuration, because it is suitable to a short- to medium-span, safer against a differential settlement and also the analysis is not complicated. It consists of a span supported at one end by a fixed bearing and at the other by an expansion bearing. Where a bridge consists of a series of simple spans, there is no stress transfer from adjacent spans. In a continuous unit, the superstructure system is continuous over one or more supports. The associated benefits may be reduction in size and fewer deck joints. Cantilever spans may be introduced in a bridge system, if this solution results in economy and simplifies the structural configuration. Cantilever spans may be used in combination with suspended spans which may be connected to the cantilever portion by a link or by a pin.

A relationship between the girder bridge types and the suitable span length is shown below.

Table 4.2 Type of Steel Bridge and Span Length

Type \ Span (m)	10	20	30	40	50	60	70	80
Simple Composite H-Beam Bridge		—	—					
Simple Composite Plate Girder Bridge			—	—	—			
Simple Composite Box Girder Bridge					—	—	—	
Continuous Plate Girder Bridge				—	—	—		
Continuous Box Girder Bridge					—	—	—	—

(2) Composite Construction

Concrete deck for steel beam and girder bridges may be designed and constructed on the basis of either composite or noncomposite behavior. With composite construction, the effective area of the slab can be calculated and used in determining the moment resistance of the section. The

required number of shear connectors must be calculated and furnished. These are generally headed studs that are welded to the top flange. Overall economy depends upon the cost of the installed shear connectors and the reduction in steel weight that can be obtained.
However, composite construction is frequently the economical choice.

(3) Economical Design

Suggestions for maximum economy of steel beam and girder bridges may be summarized as follows;

- Develop and take bids on as many alternative designs as practical. Include rolled beams and plate girders, and alternative details such as cover plates for rolled beams.
- Consider higher strength steels in general.
- Consider wider stringer spacings and develop realistic cost comparisons.
- Carefully evaluate change in flange plate size, because flange splices are costly. Consider allowing the fabricator the option of continuing the heavier plate to eliminate the splice.

3.2 Deck

Decks for steel bridges can be constructed of timber, concrete, or steel.

(1) Timber Decks

For bridges on unpaved roads or low-volume roads in rural environments, timber decks can be serviceable. But timber is at a great disadvantage because of high cost and the short durability. The choice then is usually between concrete and steel.

(2) Cast-in-Place Concrete Decks

Where light weight or speed of construction is not prerequisite, cast-in-place concrete decks prevail because they easily conform to the top of the supporting superstructure and to the required surface profile. Cast-in-place concrete decks also easily accommodate concrete side walks and outside safety barriers. This may be the most common and cheapest.

(3) Steel Decks

Sometimes the weight of the deck needs to be minimized. This is true when replacing the deck on an existing superstructure of limited strength. This is one of the most expensive method of deck.

3.3 Design of Main Girder

(1) Types of Steel Girder

There are two types of steel girder frequently used as a main component of a composite or noncomposite girder, they are a rolled beam and a plate girder.

1) Rolled Beam

The rolled beam is a steel girder which has been formed by hot-rolling. The most common type of rolled beam used as a primary member in highway bridges is the wide-flange variety. But in Chile, the "rolled beam" is usually fabricated and assembled by welding into the shape.

To maintain an economy of material, rolled beams are sometimes equipped with a rectangular plate, or cover plate, at the bottom flange. The cover plate increases the ability of the stringer to resist flexure without having to use a larger size rolled beam or plate girder. As we will see, however, the cover plate also increases the potential for fatigue damage by introducing stress concentrations at the ends of the plate.

The characteristics of using the rolled beam is that the web plate is thick enough and enables to omit attaching both vertical and horizontal stiffeners. Top flange has the same section as the bottom flange, which means unnecessarily large top flange section in terms of a working stress compared with an allowable stress. In other words, the advantage of using a rolled beam is that the work for fabrication can be minimized by using bulky materials of the rolled beam.

2) Plate Girder

A plate girder, like a rolled beam, has an I-type cross section. Rather than being hot-rolled, however, the girder is constructed from steel plate elements which are connected together with welds or bolts. For modern highway bridges, shop welding is the most predominant method. Since the designer is specifying the section properties of the stringer (i.e., flange width and thickness, web depth, etc.), a greater economy of the materials results. Plate girders gain an advantage over rolled beams as span lengths become great (see the Table 4.2).

(2) Arrangement of Main Girders

1) General

Geographically there may be needs for curved or skewed bridges, but efforts must be made to plan straight bridges instead of curved or skewed one by absorbing as much hard conditions as possible only in approach road portion.

In case that a skewed bridge, of which skew angle is sharper than sixty degrees, can not be avoided, then a noncomposite girder bridge had better be planed rather than composite one.

2) Number and Spacing of Main Girders

An arrangement of main girders means to determine the number and spacing of the girders. In order to achieve an economic design, several alternatives of combination of the number and spacing must be compared, namely attention must be paid to keep a balance of bending moments of interior and exterior girders.

Usually the girders are spaced apart uniformly two to four meters, and projected length of a slab is one to two meters. But rarely when the girder depth is severely limited, then many girders must be placed closely, and of course this may result in an uneconomical results.

3) Determination of Web Depth

The best web depth is obtained by a comparison of several alternative web depths.
Usually the optimum ratio of the web depth to the span length ranges between one nineteenth and one twenty second in case of steel composite rolled H shape girders or composite plate girders.

4) Determination of Cross-section

The required thickness of web plate is related with a use of vertical and horizontal stiffeners. To reduce the thickness and thus to save steel material, stiffeners are attached to the web plate by welding. These relations are specified at the corresponding clause of AASHTO.

When a flange plate is too wide, the whole width dose not work effectively as a part of the main girder section because of shear lag, but when it is too narrow, then the main girder is vulnerable to a bending moment about the minor axis. It is desirable that the flange width ranges between one fifth and one third of the web depth.

(3) Arrangement of Stiffeners

1) There may be arranged no or one layer of horizontal stiffeners for a span length between fourteen and forty five meters.

2) Horizontal stiffeners work most effectively, when they are attached at the height of twenty percent of the web depth away from the top of the web.

3) In case a lateral bracing is arranged in a V-letter shape, it is recommended that the vertical stiffeners are arranged in such a manner as to divide the distance between neighboring cross frames into four or six. The required minimum spacing of the vertical stiffeners obtained in accordance with specifications of AASHTO.

(4) Design of Field Bolt Joint

1) Location of the field joints

In order to find out the suitable location of field joints, these conditions as described below must be kept.

- It has to be located at almost middle between the two neighboring vertical stiffeners.
- It is preferable to determine the location in such manner as to make the block lengths of main girders similar, and the transportation of the elements is convenient.
- It is desirable, in case of bolting, that the field joints are located where no reinforcement of tensile flange plate is necessary because of the loss of sectional area due to bolt hole.

2) Use of High-strength Bolts

In Chile, steel beams have been connected by welding in the field so far. But high-strength bolts are commonly used for the purpose in many countries including the United States and Japan. Sections are joined by high-strength bolts, using web and flange splice plates. Bolts may be installed using calibrated wrenches, by the turn-of-nut method, or by use of tension-indicating washers, depending on what the designer allows and what the erector prefers to use. With all method of bolting, it is important to use a procedure and sequence of bolting that will compact the joint and prevent a bolt initially adequately tightened from loosing tension when subsequent bolts in the joint are tightened.

The advantage of connection by bolting over that of welding is that the former is a reliable but simple way of connecting steel beams, if only the product of bolts are well quality-controlled and they are tightened in a correct procedure, where not a high skill is required.

(5) Arrangement of Shear Connectors

Shear connectors must be arranged in such a way where they don't interfere with a splice plate of an upper flange.

3.4 Design of Secondary Members

Secondary members act as bracing for primary members. In general, secondary members are not load bearing elements but are designed to prevent cross-sectional deformation of the superstructure frame. In addition to this, secondary members provide for vertical load distribution between stringers by permitting the superstructure to work together as a unit.

(1) Diaphragms

1) General

Cross Frames work as;

- spacers of main girders which keep the fixed distance of the main girders,
- resisting members against lateral forces such as a wind and earth quake forces,
- distributors of vertical load,
- and reinforcing members of main girders against the buckling. .

2) Structure

For steel structures, composed of rolled beam or plate girder primary members, a rolled beam diaphragm can be used. This rolled beam is usually of the channel or wide flange type cross-section. For rolled beam primary members, the diaphragm should be at least one-third or one-half the depth of the primary member. Diaphragms for plate girders should be one-half to three-quarters the stringer depth.

When the primary member in a steel superstructure is higher than about 1.2 meters or when curved girders are used, a cross frame style diaphragm is desirable. Cross frames are typically composed of steel angles in a cross (X) or vee (V) configuration.

Diaphragms are typically connected to stringers with a connection plate. The connection plate is bolted or welded to the primary members and the diaphragm. Diaphragms shall be placed in all bays and spaced at intervals not to exceed 7.5 meters in accordance with AASHTO.

End diaphragm shall be proportioned to adequately transmit the lateral forces to the bearings.

(2) Lateral Bracing

1) General

Bracing located at either the top flange or bottom flange of a stringer to prevent lateral deformation is called lateral bracing.

Need for lateral bracing shall be investigated, but if the investigation is omitted, then it is recommended that lateral bracings are placed in the exterior bays between the diaphragms for the span length of 25 meters and over.

Lateral bracing, however, can also add stability to the superstructure during construction and, for large spans, may be desirable from this standing point.

2) Structure

The bracing is similar in form to a cross-frame (i.e., laid out in an X-type or V-type configuration) of angles, other shapes or welded sections but is laid out along the length of the stringer (in the horizontal plane).

There shall be no less than 2 fasteners at both ends of the bracing members.

3.5 Protecting Steel Superstructures

So far we have discussed the design of steel highway bridges with a focus on the structural aspects of the detail design. Of equal importance, however, is the specification of systems designed to protect the steel superstructure after its construction. Whether it is the use of the paint systems or weathering steel, in today's design environment, engineers are becoming increasingly aware of the importance of ensuring the longevity of the structure they design.

To many designers, the application of a protective coating to a steel superstructure may almost be an afterthought. There is an obvious need to protect an exposed steel superstructure against the corrosive effects of natural and man-made elements.

CHAPTER 4 SUBSTRUCTURE

4.1 General

(1) Basic Principle

The substructure will be so designed that the load from the superstructure and the loads applied directly to the substructure are safely and economically transmitted to the foundation, and also that the requirements of support conditions for the superstructure are satisfied.

(2) Selection of the bearing stratum

The bearing stratum of the substructure will have sufficient bearing capacity; stable and unaffected by weathering and scouring.

(3) Selection of the structural type and materials

Structure type and materials will be selected considering the type and load of superstructure, the allowable maximum displacement of the support for the superstructure, the influence of river flow, the conditions of the foundation ground and construction work.

(4) In general, two or more different structure type will not be used in the construction of a foundation. However, final decision will be made after sufficient study is made regarding safety factors.

(5) Design drawings

The design conditions will be clearly indicated in the design drawings. In cases where it is necessary to alter the design conditions at the time of construction, the approval of the engineer must be obtained.

4.2 Substructure

1. Determining of support conditions and location

(1) Support conditions

The support condition for superstructure can be classified as follows.

- Fixed support allowing rotation only
- Movable support allowing rotation and sliding

Fixed support allows rotation resulting from superstructure deflection, and provide resistance against sliding. Movable support, however allows both rotation and sliding. Any one of the deformational loading conditions can initiate movement in the supports. This loading condition includes movement resulting from creep, shrinkage, settlement, up-lift, and thermal forces. In addition to movement due to deformational loading, some temporary loading conditions can also initiate movement in supports. An example of this would be movement resulting from the seismic forces.

(2) Location for fixed and movable support in case of simple span

Inertia force of superstructure resulting from seismic movement in the longitudinal direction of bridge will work usually on the fixed support. Accordingly, abutment and pier which are located on the shallower bearing stratum should be the fixed support in consideration of economics (Figure 4.4). In the same way, the fixed support should be placed at a lesser height of substructure.

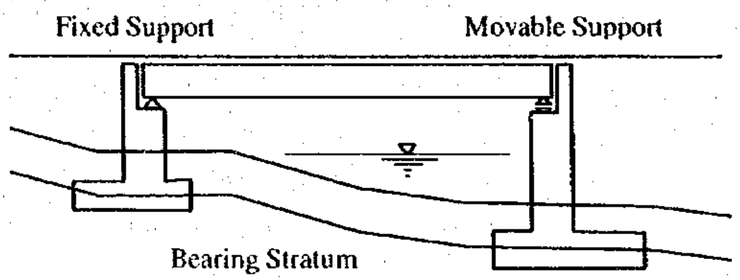


Figure 4.4 Selection of Support Condition

(3) Location for fixed and movable support in case of continuous span

In case of a long continuous span, fixed support should be located on an intermediate pier. Otherwise, at the end of a continuous span, the space between the abutment parapet and the girder end must be wide enough to withstand the thermal expansion of girder. It may be a disadvantage for the expansion joint must be large to allow ample movement.

2. Determining the Support Length

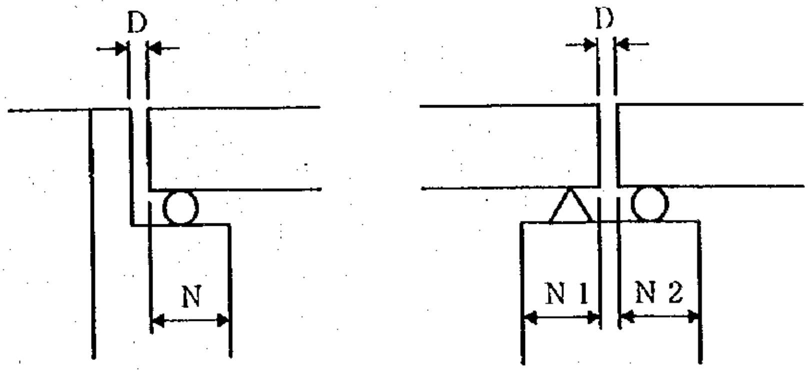


Figure 4.5 Support Length

1) Minimum bearing support length will be provided for the expansion ends of all girders Distance N is specified in AASHTO (Article 4.9.1—Division I-A), and classified for each seismic performance category.

In case of SPC-A,B

$$N=203+1.67L+6.66H \text{ (mm)}$$

where

L= length, in millimeters, between ends of bridge deck. For hinges within span, L will be the sum of L1 and L2, the distances to either side of the hinge. For single span bridges L equals the length of the bridge deck.

In case of SPC-C,D

$$N=305+2.5L+10H \text{ (mm)}$$

The size of bearing shoe must also be considered the shear stress at the corner.

2) The gaps between the end of girder which the side of expansion and other side shown Figure 4.5, the D will be considered computed according to thermal extension, shrinkage, creep, and deformation of girder due to live loads and prestress.

3. Determining the Width of Stems

1) In general, the width of stems of substructure may be determined in the same way as the road width.

2) In Figure 4.6 "S" should maintain a distance considering safe for shear stress.

3) In case of the existence of a wall structure at the side as shown in Figure 4.6, the space should be more than 50cm to allow for maintenance work.

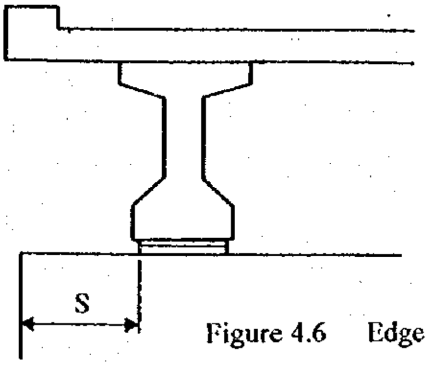
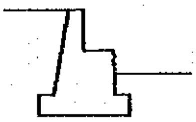
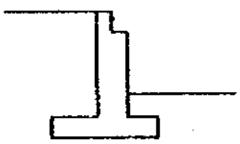
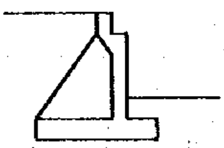
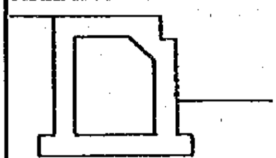


Figure 4.6 Edge Distance

4. Determining the shape of substructure

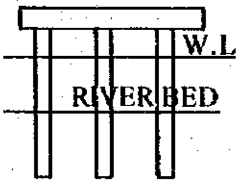
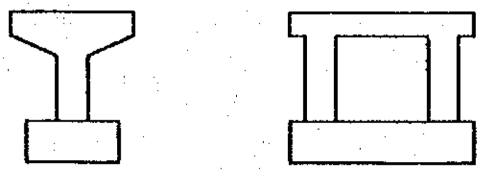
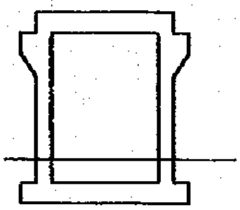
1) In generally, the types of abutment are classified as shown Table 4.3.

Table 4.3 Types of Abutment

TYPE		HEIGHT	CHARACTER
GRAVITY		H≦4-5m	• By making the abutment massive, compression is only stress at work. • Simple structure, easy construction.
HALF GRAVITY		4≦H≦6m	• Structure designed to be lighter, distributing reinforcing bars on the side receiving tension stress.
T TYPE		5≦H≦11m	• Greater in height than the gravity type, reinforced concrete type may be more economical. • Weight of earth behind wall stabilizes the structure. • Interchangeable with "L" type depending of conditions of location.
BUTTRESS		H≧10m	• Besides being applicable to higher situations, this type in general is more economic. • Care must be taken during construction as the thickness of sections is in most parts small.
RIGID FRAME			In general, this type is used in situations of greater height and requiring greater horizontal force. Also useful for separating pedestrians from road traffic.

2) In general, the types of pier are classified as shown in Table 4.4.

Table 4.4 Types of Pier

TYPE		APPLICABLE CONDITION	CHARACTERISTICS
PILE BENT		• Sites in which the construction of cofferdam would be difficult.	• Construction cost is generally less. • Little horizontal resistance in the longitudinal direction.
REVERSED T TYPE	• Wall Type:  • Over Hanging Type 		• Widely used. • In case of skew type bridges, single column type would be more efficient considering flow of river water. • Over hanging beams are mostly designed just above the high water level.
RIGID FRAME TYPE			• Generally, used in cities as viaduct. • The space of the box inside can be used as a pedestrian walkway.

4.3 Foundation

1. General

(1) Selection of the type of foundations

The type of foundations will be selected taking into consideration the following factors;

(a) Geographical and geological features

(b) Characteristics of the structure

(c) Working conditions

(d) Others

(2) Classification of the type of foundations in design

The design type of foundations are generally classified as follows.

(a) The spread foundation and the caisson foundation are classified in accordance with Table 4.5.

Table 4.5 Classification of spread and caisson foundation

Type of foundation	Df / B		
	0	1/2	1
Spread foundation		←	
Caisson foundation			→

where Df: effective embedded depth

B: shorter width of foundation

(b) The caisson and the pile foundation are classified as in Table 4.6.

Table 4.6

Type of foundation		βl					
			0	1	2	3	4
Caisson foundation			←				
Pile foundation	Short Pile (pile with finite length)				←		
	Long pile (pile with semi-infinite length)					→	→

where l: effective embedded length of caisson or pile

β: characteristic value of caisson or pile(cm^{-1})

$\beta = (kD/4EI)^{1/4}$

EI: flexible rigidity of caisson or pile ($kg\text{-}cm^2$)

D: width or diameter of caisson or pile (cm)

k: coefficient of horizontal subgrade reaction of caisson or pile(kg/cm^3)

(3) Basic principle in design

(a) The foundation must be stable against bearing, overturning and horizontal movement.

(b) The displacement of foundation must not exceed the allowable displacement.

(4) Embedded depth

1) Selection of bearing stratum and design of embedded depth

(a) The embedded depth of the spread foundation and the caisson foundation must be designed so that the foundations are supported by stiff bearing stratum.

(b) The embedded length of the pile foundation must be designed taking into account of such factors as the type and function of superstructure, load supporting mechanism and workability of piles.

2) Design ground surface

Design ground surface in normal situations will be determined taking into account the following factors;

(a) Scouring and settlement of ground surface.
(b) Consolidation settlement.
(c) Freezing and thawing.
(d) Disturbance of soil due to construction work.

(5) Soil constant required in design

The soil constants for the design of foundation will be determined after making sufficient study of the results of surveys and soil tests.

(6) Ground reaction and displacement

Ground reaction and displacement will be calculated after making sufficient study of the results of various kinds of survey and soil tests. In this case, it is necessary to calculate the amount of elastic settlement for the sandy soil and the amount of both elastic and consolidation settlement for the cohesive soil.

1) The coefficient of subgrade reaction

The coefficient of subgrade reaction will be determined in accordance with

$$K = \frac{p}{\delta}$$

formula as follows;

where k: coefficient of subgrade reaction (kg/cm^3)
p: load intensity (kg/cm^2)
δ: amount of displacement (cm)

2) Ground reaction and elastic displacement

The ground reaction and the elastic displacement will be calculated by using the coefficient of subgrade reaction.

3) Consolidation settlement

(a) The consolidation settlement will be calculated when the layers of cohesive soil to consolidate exist within a depth of three times the minimum foundation width from the bottom of foundation.

(b) The consolidation settlement of the layers of cohesive soil will be calculated taking into account increased vertical stresses in soil due to the load acting on foundation and the pre- consolidation stresses.

(7) Deeply embedded foundation in the soil that settles due to consolidation

When the foundations are deeply embedded where consolidation settlement may occur, effect on the foundations due to ground settlement such as negative friction, etc, shall be examined.

(8) Foundation constantly subject to an uneven load

It is necessary to make a careful study concerning the foundations on which an uneven load acts and of which lateral movement is anticipated.

CHAPTER 5 BRIDGE ACCESSORIES

5.1 Expansion Joint

Bridge roadway expansion joints are provided to accommodate the thermal changes in the superstructure, and, in the case of prestressed-concrete bridges, to accommodate creep shortening of the structure as well. They are required at abutments that are restrained against longitudinal movement and at the end of supported superstructures free to translate due to provision of expansion bearings.

In some long-span steel bridges, expansion joints and expansion bearings must also accommodate change of length of span due to live load stresses. Expansion joints are not required in short bridges where movement is small - for example, in steel bridges with span less than 15 meters. For these longer bridges, designs that eliminate or minimize bridge expansion joints, without introducing problems in the approach roadway or causing distress in the superstructure or substructure, are favored.

Deck joints fall into two classes: open and closed. An open joint is nothing more than an opening between the concrete deck and an adjacent structure element (e.g., deck/deck, deck/abutment backwall, deck/approach slab). Sometimes open joints are equipped with steel angles at the opening to create an armored open joint. An armored prevents some debris from entering the joint and will offer greater protection to the faces of concrete elements.

Several types of expansion joint sealing devices are available. Properly sized and installed, they can greatly reduce, if not eliminate, drainage through the joint.

(1) Open Joints

The obvious deficiency of any open joint, however, is its inability to prevent leakage and its susceptibility to deterioration. In addition to this, an open joint can only handle small longitudinal movements. Because of these inadequacies, open joints are rarely used in new structures and are predominately found in older, short span bridges.

(2) Filled Joints

For short span bridges requiring small joint movement, a filled joint can be used as an alternative to the open joint discussed above. Filled joints can be either preformed or field-formed, consisting of a sealer which is either inserted or hot poured into the joint, respectively.

(3) Compression Seal Joints

A compression seal consists of an elastic material which is squeezed into a joint opening coated with an adhesive lubricant. The most popular material for compression seals is extruded neoprene (polychloroprene) with an open cell cross section.

(4) Strip Seal Joints

A strip seal uses a preformed strip of elastomeric material which is placed between dual steel rails that are anchored to the face of the joint opening. Most joints of this type utilize a neoprene gland as the sealant. Unlike a compression seal, which is squeezed into place, the strip seal is mechanically fitted to its steel rail assemblies.

(5) Finger Plate Joints

Finger plate type joints consists of steel plates which are married together through extending fingers, and allow a wide gap movement. A finger plate joint can be considered an open joint. Therefore, it is necessary to protect substructure elements from leakage. This is accomplished through the use of a drainage trough, made of elastomeric material, which is installed underneath the finger plates and at the centerline of the joint.

5.2 Bearings

AASHTO requires that steel bridges with spans of 35 meters or greater have a type of bearing employing a hinge, curved bearing plates, elastomeric pads, or pin arrangements for deflection (rotation) purposes.

Bearings consists of some or all of the following components:

- Plate resting on the substructure bridge seat
- Rotation device
- Sliding device
- Movement restraining devices, or "keepers"
- Sole plate attached to the superstructure

Bearings may be fixed bearings, providing for rotation only and preventing differential movement between superstructure and substructure, or expansion bearings. Sliding expansion bearings have a finite capacity depending on the length of the contact surface, or may employ keepers to limit the movement. The range of movement accommodated by the bearing should be greater than the calculated movement.

The elastomeric bearing, in which superstructure translation can be accommodated by shear, is often the most economical type for both steel and concrete bridges. This bearing consists of an elastomer such as natural or synthetic rubber (polychloroprene, or neoprene), with or without internal reinforcement.

In addition to accommodating horizontal movement by deforming in shear, elastomeric bearings can accommodate superstructure rotation. Another desirable attribute of elastomeric bearings is that they can tolerate movements or rotations in directions other than longitudinal. For structures with large skew or curvature, where it is known either qualitatively or quantitatively that such out-of-plane rotations exist, this is a desirable quality.

5.3 Deck Drainage

Adequate drainage of the deck is important for safe operation during rainstorms, to prevent accumulation of rainwater or snowmelt that could freeze and cause skidding, and so prolong the life of the deck by removing standing water, which would otherwise contribute the water element necessary for corrosion.
Scuppers of adequate size and spacing must be carefully determined.

5.4 Railings

Although the primary purpose of the traffic railing is to contain the average vehicle using the structure, consideration should also be given to (a) protection of the occupants of a vehicle in collision with the railing, (b) protection of other vehicles near the collision, and (c) appearance and freedom of view from passing vehicles.

Railings shall be provided along the edges of the structures for protection of traffic and pedestrians.
The railings should provide a smooth, continuous face of rail on the traffic side with the posts set back from the face of rail.

As to pedestrian railings, railing components shall be proportioned commensurate with the type and volume of anticipated pedestrian traffic.
Materials for traffic railings shall be concrete, metal, or a combination thereof.

(1) Steel Railing

Materials and fabrication of steel railings shall conform to the applicable requirements of "Steel Structures".
All exposed welds shall be finished by grinding or filing to give a smooth surface.
Steel railings shall be carefully adjusted prior to fixing in place to ensure proper matching at abutment joints, correct alignment, and camber throughout their length.

Unless otherwise specified, anchor bolts, nuts and all steel portion of railings shall be galvanized. When painting is specified, the type and coating shall conform to the requirements.

(2) Concrete Railing

Concrete railings, depending on the design, may be constructed by the cast-in-place, precast or, when approved, the slip form method.

Forms for cast-in-place, railing shall not be removed until adequte measures to protect and cure the concrete are in place and the concrete has sufficient strength to prevent surface or other damage caused by form removal.