First decisions in the project process

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First Decisions in the Project Process

Premières décisions dans le processus du projet

Erste Entscheidungen im Entwurfsprozess

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SUMMARY

The design of a bridge requires careful planning and sound decision making. Experienced, skilful engineers should be responsible for the project planning from the very beginning. The development of an engineering project passes through the phases of appraisal, feasibility, design and construction. Many important decisions have to be made in the first two of these four phases. They are the first decisions in the project process. Such choices as bridge location, required amount of data acquisition, and evaluation of all data, design forces, and finally the preferred bridge type are all part of the decision making process.

RESUME

Le projet d'un pont exige une soigneuse planification et de nombreuses décisions prises à bon escient. Des ingénieurs capables et expérimentés devraient être responsables de la planification du projet dès le début. Le développement d'un projet de génie civil comporte les étapes d'avant-projet, de faisabilité, de projet et de construction. De nombreuses décisions importantes doivent être prises dans les deux premières étapes. Elles représentent les premières décisions dans l'élaboration du projet. Des choix tels que l'emplacement du pont, l'ampleur des données nécessaires et l'évaluation de toutes ces données, les cas de charge et finalement le type de pont prévu font tous partie du processus de décision.

ZUSAMMENFASSUNG

Der Entwurf für eine Brücke erfordert sorgfältige, genaue Planung und klar überlegte, technisch einwandfreie Entscheidungen. Erfahrene, facherprobte Ingenieure sollten von Anfang an für die Planung verantwortlich sein. Jedes Ingenieurprojekt durchläuft die folgenden Entwicklungsphasen: allgemeine Abschätzung und Beurteilung der technischen, wirtschaftlichen und sozialen Voraussetzungen und Folgen; die Durchführbarkeit des Projekts; der Entwurf und die Konstruktionsplanung; der Bau. In den ersten zwei dieser vier Entwicklungsstufen müssen die wohl folgenschwersten Entscheidungen getroffen werden: Lage und genaue Ortsbestimmung der Brücke; Sammeln und Erfassen der erforderlichen Daten und deren sorgfältige Auswertung; statische Erfordernisse und Folgen des Entwurfs; Beschluss über die zweckdienlichste Art und Ausführung der Brücke.

Introduction

Bridges are not just built, they are born. The birth of a child is the responsibility of just two people. However, the birth of a bridge may be the result of the action of a number of people all having certain areas of responsibility. The child grows as a result of physiological processes in the body of the mother. A bridge grows from the mental processes of the engineers and the physical action of the builders. As a child is a wonderous product of a supreme plan, so a bridge should be the end result of careful and detailed planning.

Upon the birth of a child, it becomes the ownership of the parents. Upon the birth of a bridge it becomes the property of the people (except for the rare cases of privately owned bridges). As the parents of a child do and should feel pride in their offspring, so should the engineers and tradesmen who have been responsible for the birth of a bridge feel great pride and joy in their creation. If the bridge project has been successful, then not only the creators, but also all those who own and use the bridge should find pleasure and satisfaction in this new creation.

Successful bridge developments don't just happen they have to be carefully created. This has been the case from the early beginnings of time. The Roman builders of the Pont du Gard certainly must have planned well and completely to have built a bridge to carry both water and people, and to last for over 2,000 years. Can you imagine the pride of the builders, whether proud Roman governor or slave, when all was finished and they stood on the hillside overlooking the structure and contemplated what they had created. This same feeling of accomplishment must have been present when other great bridge structures, such as the Firth of Forth railroad bridge (Fig. 1), were completed.

Fig. 1 Firth of Forth Railroad Bridge, 1889

The world has been blessed with men who appeared on the scene at the right time with the necessary attributes of intelligence, skill, ambition and determination to create bridges where they were needed. Such men of history as St. Benezet, Gaddi, Perronet, Stephenson, Baker, Maillart, Eads and Roebling, as well as many engineers of this Twentieth Century have given the world great bridge structures,

structures which have been so necessary for the development of civilization and a high standard of living.

What does it require to produce a successful bridge? The answer to this question is not simple.

A successful engineering project requires the bringing together and synthesis of many aspects of science and art. In the period of time up to the nineteenth century bridge building was primarily art. Since the early nineteenth century science has been replacing and supplementing art. Today, the bridge engineer must have at his command a knowledge of science that is more than double, maybe triple that which was available fifty years ago. The key to success is a project engineer who can bring together all the necessary knowledge, to organize this knowledge, and then develop the plans and specifications and finally produce the structure itself.

Steps in Project Development

In a total project development there are four basic steps. These are:

- 1) Appraisal
- 2) Feasibility
- 3) Design
- 4) Construction

These four steps must be taken in the order listed. Each activity must follow the previous activity and each step requires the expertise of a qualified engineering organization. Non-engineers may be involved in some of the activity, primarily in steps 1, 2, and 4. In bridge projects the involvement of non-engineers in decision policy will most likely be minimal. Such limited involvement will be primarily in steps 1 and 4.

A brief outline of the procedures involved in each step will be described.

Appraisal

This activity will involve the first investigations of a project. It will consist of input to highway planning to determine the most favorable location for a new highway or realignment of an old highway. The cost of a bridge or bridges on the total cost of a highway can be minor or major. Where the cost of bridging is major, it will be necessary to devote considerable time and effort to this step in the project. Site choices will have to be selected. This will involve close coordination with the highway engineers to determine the possible roadway locations.

Preliminary surveys will have to be performed to determine the total bridge lengths at possible sites. Aerial surveys may be sufficient to supply the needed survey data for the preliminary appraisal study. Some on-site surveying may be necessary to more closely define the length of bridge crossing and elevations.

In addition to preliminary ground surveys, general hydrological information is necessary. The third item in the necessary data set is a geotechnical evaluation. The geotechnical data will not be extensive at this phase of the project. A general geologic study should indicate the probable soil profile and slope stabilities.

With this information, the bridge engineers can appraise the site location or locations to ascertain the possible bridge size and types that will be satisfactory. If the study of the general site location is favorable then the project process can move into the next phase which is the feasibility study.

Feasibility

In the case of bridge design and construction projects the feasibility study is just a more detailed extension of the work performed in the appraisal phase. This work will have as its objective the final location of the bridge and a preliminary cost estimate. With an evaluation of all logical bridge sites performed the optimum location as determined from the information already gathered is selected. Further data is then required.

Existing roads or streets may dictate the exact location of a bridge even though there may be a difficult situation in locating a new bridge at this location. The construction of the new Dusseldorf-Oberkassel Rhine River Bridge was a case in point (Fig. 2). Because of existing street alignments the new bridge had to have the same alignment as the old bridge yet a crossing had to be maintained.

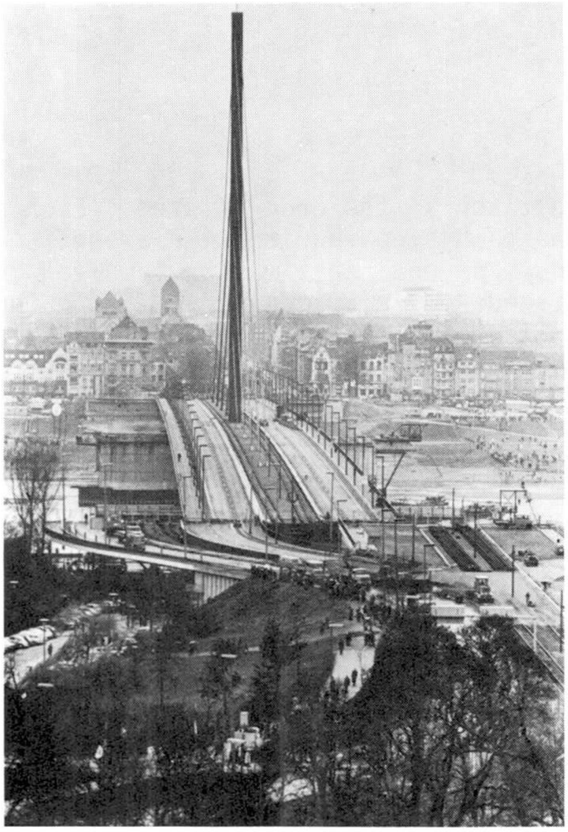

Fig. 2 Dusseldorf-Oberkassel Bridge

With the site finalized, the detailed data can next be gathered. This necessary data gathering will require a detailed site survey. The site survey will require a topographic profile along the centerline of the bridge as well as along lines approximately 50 to 100 feet each side of the centerline. If the terrain at the bridge site is uniform in gradiant then these other two supplementary profiles may not be needed. The profiles will also require the determination of low, high, and median water levels.

Hydrographic data extending over many years may be readily available for a stream crossing. A bridge in an undeveloped region where stream flow data is unavailable may require an extensive hydrologic study of the entire region. This, however, is usually unnecessary for bridges over streams in developed regions of the world. Part of the required stream flow data will be the peak velocity of the water at various stream elevations. Very high stream flow velocity such as possible in mountain regions may preclude the use of piers within the region of high stream flow. In cold regions, the consideration of ice thickness and ice pressures at stream crossings should be part of the feasibility study. The required waterway opening for water transportation can be a major factor in maximum bridge span and thus bridge type.

Data that are necessary for a complete feasibility study includes a geotechnical evaluation of the bridge site or sites. At this stage of the study, one or two soil borings may be sufficient to determine the range of soil bearing strengths and whether or not piles will be needed. If the upper soil level evaluation indicates piles will be needed then the borings should be continued to a depth that would support point bearing piles or to a depth that would be necessary for friction piles.

The project engineer is always confronted with the problem of selecting the desirable number and location of soil borings at the preliminary or feasibility stage of the project. Structure evaluation has not proceeded sufficiently at this period in the project to finalize the abutment and pier locations. In the final design stage, borings should be taken at each one of these locations. As a minimum, one or two borings at any one site are necessary for the feasibility analysis. From a consideration of time and cost it would be preferable to take all required borings for both preliminary and final design in one operation rather than in two separate periods, which on a large and complex project may be separated by a considerable time period. A decision has to be made from the following possible choices:

- 1) Drill one or two holes at the time of the preliminary study, and before the final location of abutments and piers. Return the drill-rig later for final borings.
- 2) Make a concentrated study of bridge types and select the most probable final location of piers and abutments and perform all the borings at one period of time.

A selection procedure should be based upon:

- a) Number of bridge types that appear feasible and probable bridge length.
- b) Difficulty of bringing drill-rig into the area.
- c) Whether a governmental design organization, or contracted consultant, is to select the bridge type and prepare the final design drawings, or if tenders of alternate designs are to be accepted.
- d) Whether at the time of preliminary study more than one site is under consideration. If this is the situation, then the first of the above two choices will be most appropriate.
- e) General geology at the bridge site. If sub-soil conditions appear very uniform throughout the area then two or three borings may be sufficient for preliminary and final design.

The feasibility study will include the evaluation of sources of supply of materials for the bridge construction. Location of aggregates for concrete, cement supply and availability of ready-mix concrete plants should be studied. The location of steel fabricating shops and supply and cost of rolled steel plate and sections will be determined. Depending on the span length and location of the bridge, a definite selection of concrete or steel superstructure may be made. This decision will be made from a basis of bridge cost, maintenance, and aesthetics. In some cases this material decision may be very difficult to make, even at the final design stage.

The type and condition of access roads to the bridge location may have a bearing on not only the type of bridge, but also on the superstructure materials. Accessibility of water transportation to the bridge site is also a major factor in design selection.

In this day and age an important feature of any construction project is the evaluation of the environmental impact of the project. In the USA an environmental impact statement is required by law for each construction project. The environmental impact report may be rather simple for small bridges on a major highway project. In fact, the environmental impact report for a major highway project will most likely include all bridges.

When the project consists of only a bridge and short approach roads then an environmental impact report will be part of the bridge project. For a large bridge in an urban area, this report will require the gathering of considerable data. A bridge in a special scenic area will require special emphasis on an environmental study. This study will require the gathering of data on subjects as wide ranging as economics, sociology, botany, zoology, and biology. Specialists in these areas will have to be engaged to gather the necessary data and prepare sections of the report. It will be necessary to engage the people required for these assignments at a very early time in the project to be sure there is no delay. The preparation of the environmental impact statement has in some instances caused considerable delay and added much cost to construction projects. The scheduling of the work in the preparation of the environmental impact statement should be done with special care and very early in the project.

In the USA, a major construction project will require a public hearing. At this hearing any citizen can ask questions and make statements which are recorded for the review of public officials. It is very important that all aspects of the environmental impact are thoroughly covered in the report. If some task has been left undone then an opening is presented for obstructionists or even well-meaning citizens to demand a delay in the project until that neglected area has been investigated. In the years shortly after the passage of the environmental protection law in the USA, many engineering firms took the preparation of the environmental impact report lightly. This action caused many problems and delays in the prosecution of construction projects.

The public likes to see several alternatives presented for any major project with the pros and cons for each design. A number of years ago in California the public demand was such that a continuous truss bridge design had to be discarded and a new final design of a shallow box girder with orthotropic steel deck substituted. This was done after the final design drawings for the truss had been prepared. The aesthetic quality of the truss design was opposed by several important citizen groups. In retrospect, I believe the citizens were right.

It is a well known fact that even though the private citizens do not usually make the final design selection, there is better acceptance of the decision if they have had the opportunity to voice their opinions.

Upon the evaluation of all the collected data, the feasibility report can be prepared. In many cases this is called the preliminary design study. The study will cover the following investigations and several important decisions will be made at this stage of the project.

- 1) Selection of most feasible bridge site and evaluation of alternate sites.
- 2) Cost evaluation of the project. This can only be an estimate since no detailed design has been performed. Experienced bridge engineers should be able to provide a sufficiently accurate cost figure in order to establish the feasibility of financing the project.
- 3) A comparison of the aesthetics of different bridge designs should be made and the cost differentials evaluated. A more costly bridge may be preferable because of its more pleasing aesthetic qualities. A major decision is whether to use a bridge of many short spans (Fig. 3) or to eliminate piers and use a longer span (Fig. 4).

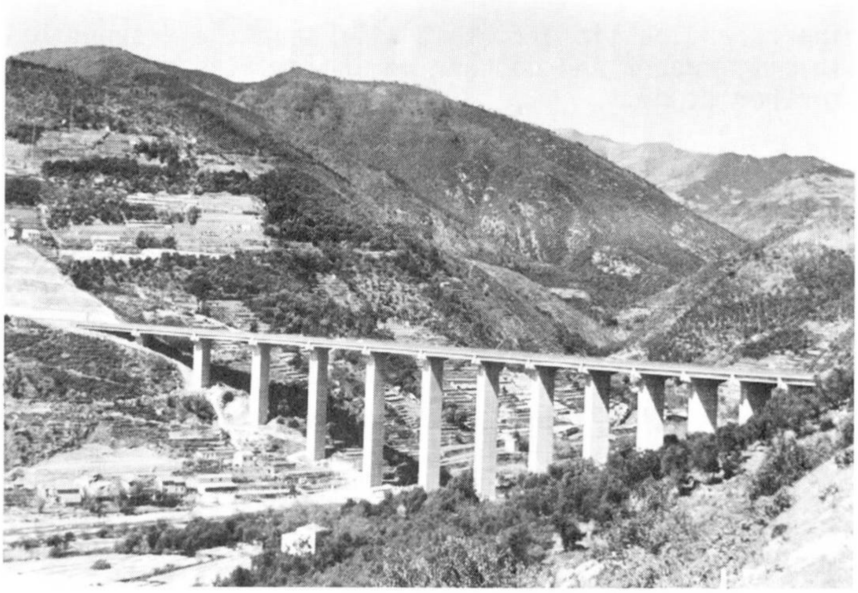

Fig. 3 Multiple Span Bridge

Fig. 4 Long-Span Bridge;
Kniebrucke-Rhine River, W. Germany

- 4) The environmental impact of a bridge at a given site should be evaluated and also the impact at other alternate sites should be prepared if there are any appreciable differences at alternate sites.

- 5) A comparison of bridge types should also be made based upon the maintenance costs. Drastic deterioration of bridges have taken place in recent years in northern climates of the U.S.A. where deicing salts are used on road surfaces and bridge decks. This extreme deterioration has occured in both steel and concrete materials.
- 6) Special loadings or environmental hazards should be investigated and quantified.

The conclusions of the feasibility report will contain the recommended bridge type and cost and also a comparison of other competitive bridge types based upon the previously listed evaluation parameters.

The review engineers and public officials will have the responsibility of evaluating the feasibility report and concurring in its findings and conclusions or return it for further study.

Upon approval of the feasibility study and its recommendations the project enters into the design phase.

Design

The design phase requires several important decisions in the early stages of this time period. The most important may be the selection of the design firm or design team. It is common in the USA to have the same engineering organization which prepared the feasibility study do the final design. There have been notable exceptions to this rule, however. Some governmental rules and laws in certain localities have prohibited the engineering firm which prepared the feasibility report from receiving a contract for the final design. This rule is for the purpose of having a completely unbiased feasibility report. In this situation a negative feasibility recommendation would not deprive the organization rending such a verdict from a future design contract.

In some projects a state engineering department may do both the feasibility study as well as the final design. On large projects the design may be contracted to a consulting engineering firm after the feasibility study has been prepared by the state highway department.

In countries where the tender type of contractural relationships exist, the final design is quite likely performed by a separate organization from the one preparing the feasibility report.

The beginning of the final design will require several decisions. Before such decisions are made, it is first necessary to outline all the required tasks to complete the final design phase of the project. After a detailed listing of the individual tasks, then a list of the required decisions and the necessary required data should be made. With this list of tasks, decisions, and required data a procedural bar chart can be made with each of these items in its proper time slot. Without such a chart, the project may experience delays and resulting financial waste. If the bar chart is skillfully prepared and followed then when the data necessary for a design decision or design operation is required it will be available.

One of the first decisions in the final design phase is whether additional subsoil investigation is needed. If additional borings are required, then expeditious action is necessary. In most projects the design of the superstructure can proceed while further geotechnical exploration is taking place.

Some bridge designs may be so unique or have such characteristics that research is needed. If such is the case then this work must be started early so as to not cause undue delays. Such research may be wind tunnel tests and other aerodynamic investigations. It may be necessary to make readings of wind direction and velocities at the bridge site. This data will most likely be required when a cable suspended bridge is the selected type.

In some regions of the world, extensive studies on the earthquake response of the bridge structure will be required. It may be necessary to perform model tests on a shaking table as was done for the Ruck-a-Chucky Bridge (Fig. 5). Special connections, roadway surfaces, expansion devices, bearings, etc., may also require special evaluations.

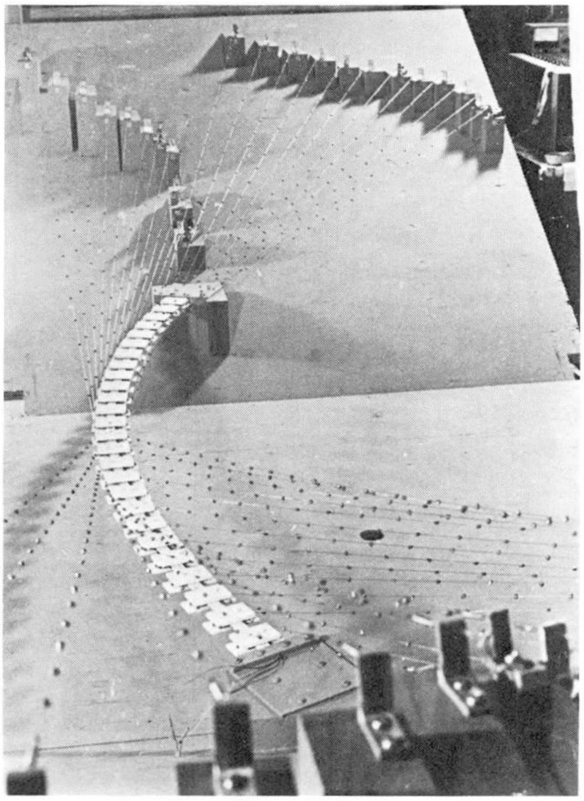

Fig. 5 Seismic Model of
Ruck-a-Chucky Bridge - California

If the feasibility study did not investigate the proper design loading then this decision is an early high priority. In most countries standard design specifications dictate the design live load as well as other design forces. For large bridge projects, and especially long span bridges, these standard loadings as well as other aspects of the design specifications should be scrutinized for their accuracy as applied to the structure in question. Blind adherence to codes can possibly lead to waste of material or a reduced safety factor. ASCE presently has a technical committee activity studying all types of loadings on bridges.

A decision having an effect upon the economic well being of the design firm will be the assignment and allocation of engineers to the project. Man-hours of engineering effort should be estimated at the very beginning of the design phase of the project and the required number and experience of the engineers determined. A critical path chart will help in reaching the manpower requirements. Requirement of special consultants need to be recognized and steps taken to acquire their services. Selection of the best project engineer requires careful consi-

By proper planning and sound decision the work of the bridge project can move through the phases of appraisal, feasibility, and design to the final phase of construction. The construction phase will also require important decision. However, if the decisions in the first phases of the project have been sound, and have been based on good engineering principles, then the construction phase should proceed in order and dispatch. The final result will be a safe, attractive and economical structure; a structure that has been born of the minds and talents of the skilled professionals, and a structure that will be admired by all those that behold it.