Serviceability and maintenance

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Serviceability and Maintenance

La serviciabilité requise et l'entretien

Nutzung und Unterhalt

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Life Cycle Considerations for Structures

This paper presents an overview of the various life cycle aspects and procedures applicable to structures. Treatment is in broad terms as regards types of structures. Discussion covers the life of a structure from conception, through planning, design, construction and implementation of use, to the longer period of operation and maintenance, ending in demolition or abandonment. Orientation is from the point of view of how the structural engineer -- be he planner, designer, materials supplier, equipment specialist, builder or administrator -- can best serve the interests of the owner and the affected public, while working with other professions engaged by the owner and regulatory agencies of government, to improve the creation and operation of a project. It is concluded: that the optimization of the primary aspects -- functional service, capacity to serve, environmental effects, time schedules, and cost to benefit relations -- are objectives within reasonable reach; and that favorable serviceability and maintenance depend directly on adequate planning, design, and construction.

Serviceability and Maintenance -- what are they and why talk about them. The practitioner of structural theory can well say our structures are excellently designed to carry specified loads. The researcher in materials can equally well state satisfactory materials are being incorporated into structures. The builder can claim with assurance that structures are built as designed. Everybody knows that most structures last a lifetime. They are torn down when no longer needed; practically never fall down. New generations of structures have benefited from improvement in design theory, in better materials built into the structure, and in more ingenious construction methods.

There can be no quarrel with any of those statements from the point of view of the structural engineer. Certainly structures of the past have given good service, the vast majority far beyond the call of duty. Certainly maintaining them in serviceable condition has been no more than a routine requirement except in isolated cases.

Such a discussion could easily backslide into great detail. Examples of former less than perfect practices which have been corrected could be cited -- elimination of pockets which did not drain and rollers which did not roll; introduction of "weathering" steel to eliminate the need for painting, particularly where service was affected; elimination of expensive false work by segmental or slip-form procedures. Examples of adequacy and progress include: carrying loads with surprising reserve capacity; greatly improved corrosion resistant coatings; welding to achieve economy, cleanness of detail and quiet; and so on ad infinitum. It is not the purpose of this paper to discuss such details. They are different for almost any structure, varying with location and climate, type of structure, kinds of materials used, service requirements, and accidental phenomena.

In passing, the point is made that no structure is better than its details. Attention to detail is therefore essential, most particularly from serviceability and maintenance aspects. This explains in part why the best designs have usually had the benefit of participation by individuals experienced in functional design, construction, operation and maintenance. Experience is a marvelous teacher of practicality.

The intent of this paper is to discuss aspects of serviceability and maintenance from other than the engineering point of view. After all, the structural engineer participates primarily in the creation of the structure. Others establish when and where it will be built, pay for it, take care of it, use it, and eventually dispose of it. Many of the design criteria are fixed by non-engineers. They all have important points of view with respect to serviceability and maintenance, both of a direct and indirect influence.

It is worthwhile to examine these other points of view and their influence on the work of the structural engineer. A structure is a complex mechanism. An influence exerted in one area is very apt to permeate the whole complex. The better the structural engineer understands, works with, and can put himself in the position of the other decision makers the more professional and satisfactory will be his services.

As the peoples of the world more keenly realize that resources are finite, as demands on resources inexorably increase both quantitatively and qualitatively, and as need for leadership in responsibility becomes ever more essential there emerges a greater and greater need to consider more fully for any structure its basic life cycle aspects. The five primary aspects of concern are functional service, capacity to serve, environmental effects, time schedules and cost to benefit relations. In each specific case these simply stated primary aspects are comprised of many elements. The elements of significance and the weight to be assigned to each in a given case must be selected with due regard to responsibilities of all types -- human, social, economic, and monetary -- as well as technical. The value of a structure to society is measured by its performance.

The addition of non-technical considerations to the more usual technical engineering activities will be new to some structural engineers. To those who have had overall responsibility for projects and have had to develop justification for them it will be less strange. There will be those who will take the position that attempts to evaluate the above named primary aspects over the life of a structure will be futile because the time factor introduces too many variables which cannot be precisely evaluated. They can cite such items as wages, material prices, interest rates, taxes, and general economic level of activity. Certainly long-term projections cannot be precise. They are more useful on a comparative basis than on an absolute basis.

However, lack of precision is not a valid reason to avoid making the best possible analysis. As structural engineers know so well, any structure abounds with secondary stresses which cannot be precisely evaluated but this does not deter the designer from making his best possible analysis on the basis of known factors, theory, and his experience and judgment. It would be folly to merely guess at the size of structural members; and the same applies to the primary aspects named above, including their life cycle evaluation.

Almost every structure for constructive purposes (and we are not here discussing monuments whose sole purpose is to extol past achievements artistically) is related to one or more of the following:

- Housing for people, business, commerce, industry, military or cultural activity
- Production or processing of food, clothing or other items to serve people
- Transportation of people or goods to support or to benefit from production, commerce, education, health care, recreation or communications
- Utilization or control of natural resources for the benefit of people
- Disposal of the by-products of civilization.

It follows that any new knowledge, process or procedure which improves the primary aspects of a structure has a long-range significance for people. It contributes to the ways and means of improving the quality of living through enhancement of a learned art for the benefit of people. In the final analysis that is what structural engineering is all about.

The key role of the structural engineer: from the immediate point of view is to create structures superior in every respect; and from the long-range point of view is to improve the lot of mankind at a price mankind can afford to pay.

Associated with a structural project are always four main categories of people which in fact comprise a project corps. Each category deals primarily with a different set of elements as is illustrated by:

- OWNER - functional needs, regulatory controls, financial sources, amortization of cost, project timing
- DESIGN TEAM - design criteria, construction materials and procedures, equipment, environment, design methods, construction contract documents, costs and benefits, time schedules
- BUILDER - materials suppliers, labor, construction equipment, sequential schedules, weather
- USERS - functional service operations, maintenance procedures and costs, contributions to quality of living.

All of these ramifications in no way lessen the demands on the structural engineer. To the contrary, the requirements thus thrust upon him are heavy additions to the need to be completely up to date on all aspects of his primary concern -- the physical design which appropriately translates the agreed upon functional services into a structure which will advantageously provide those services. Nevertheless, the added requirements cannot be ignored. History is replete with examples of needed projects not built because of misunderstandings; and of structures built and not serving as effectively as possible.

It is therefore appropriate that I.A.B.S.E. has broadened its interests to include cognizance of economics, construction procedures and environmental, social and political factors which impinge directly or significantly on structural design criteria and thus his practice. By broadening its base of operations, structural engineering will be following more closely the systems approach which, in plain language, means considering all the indirect as well as the direct angles and consequences to achieve proper mutual and full understandings with the decision makers before irreversible action is taken at any stage of a project.

It falls to the professional designer to provide the leadership that holds together a well rounded design team that makes timely and efficient progress in the formative period leading up to an appropriate master plan thoroughly understood and agreed to by all the elements of the design corps. This professional designer may be advisor to the owner, he may be a consulting engineer, or he may also be the builder. Whatever his position, his responsibilities differ only in detail. Actually, a professional engineer should be in all of the positions named on any sizable project. The engineer's strength lies in his thorough grounding in the relations between cause and effect -- various causes, multiple effects, all kinds of ways and means of solving apparently impossible problems within the limitations of almost immovable prerequisites. His training is primarily methodological; secondarily specific. He is realistic about costs and benefits. He is geared to making progress. His whole attitude is application of knowledge to produce a useful facility.

He can cope with concepts of appropriate parameters which have been added to design criteria for design of a facility. Reference is here made to a "facility" instead of to a "structure" because many structures are a part of a system to which these new parameters apply. The structural designer is, therefore, more often than not now a member of a design team composed of many types of professionals whose various aspects of design must be integrated into a composite facility. Although to safely carry required loads and to do so economically over a long time are still primary functions for most structures, such functions may become secondary to the full purpose decided upon for the system of which the structure is but one part.

These added considerations have arisen in recent years as the result of the public becoming involved in the planning and programming of those facilities which may affect environment, the ecology, and society. The public's greatest concern to date has been with respect to visible features. In the early stages of this awakening, desires were often only partially and unclearly stated and frequently reflected an uninformed background. Only recently has the public been forced to come to grips with such practicalities as funding, finally realizing that seldom can added characteristics be provided in a facility without adding costs and that cost factors must be considered when establishing the design criteria. Such realizations have served to temper the environmental, ecological, and social demands but have properly not eliminated them. An appreciation by the public that time is of the essence is still to come. The same applies to establishment of priorities.

This evolution which has changed the decision makers from a concentrated group of specialists to a non-homogenous group has, of course, lengthened the decision-making process. Time <u>is</u> of the essence in the planning, design and construction for any needed structure or facility. Repeated reviews, particularly partial and merely negative ones, false starts, change orders and stop orders add materially to time and costs in two ways and for no good reason. The records show that projects delayed in start, subjected to prolonged periods of construction, or changed in concept during design or construction always cost substantially more, sometimes by as much as one or two magnitudes. The record also shows that delay in receiving services from a needed project always subjects the potential users to added costs for the reason that the existing facilities or lack of any are more expensive than those to be obtained from the new project -- otherwise why build the new one.

Some designs which met earlier simpler criteria for serviceability are, in the light of recent more sophisticated criteria, now considered inadequate. And, of course, since the public did not participate previously in the decision making, the public blames others for those inadequacies. During the transition, the public has been exercising authority without bearing the relevant responsibility. To continue in such a manner would lead to public bankruptcy. By brute force of budgeting realities that relationship is being normalized. Nevertheless it is still necessary for the professional structural engineers to act in a positive and constructive manner that will restore the confidence and respect of the public in the professional services they render.

Engineers cannot restore their credibility by talk alone. They must again earn that status by placing their actions in agreement with their talking, and do so in a manner which the press and the public cannot misunderstand. The cost and the time required to achieve beneficial use of the facilities created by designers, and the interactions between all parts of the system of which a structural design becomes a part have a definite bearing on regaining credibility.

Greater social responsibility for engineering based facilities is here to stay. It is in the interests of engineers to adjust to these new requirements quickly, reasonably and, as is most necessary in all parts of their work, intelligently. Frankly we have added participants in the normal interplay between cause and effect. Those causes and effects which are related to human nature can be as influential in a structural design as those related to Mother Nature.

This points up another characteristic of the structural engineer's work. The designer himself, for example, cannot be expected to become expert in detail in all aspects affecting design today. However, it has been shown by experience that the engineer as the principal will be charged with full responsiblity for the work of others in his team, including design criteria dependent upon data or often only opinions developed by social, political, and economic "scientists."

The use of empirical data and of assumptions in formulating designs is not new to engineers. Such use has been required in order to formulate mathematical relationships needed to solve for the unknowns. In the past, assumptions and empirical data have been used only when rigor was not possible by reason of the state-of-the-art. Always the use of assumptions and empirical data was founded on relevant experience and applied with careful judgment to meet the unrelenting realities of the physical world. The so-called social, political, and economic scientists in stating their design criteria have often (a) paid more attention to their concept of what the future should be than to experience, and (b) have often indulged in wishful thinking. In contrast the engineer knows that sky hooks will not support loads and, therefore, never tries to employ them. His failures are too quick and visible. Much benefit would result if the same certainty of consequence would become readily visible with respect to design criteria related to environmental, ecological, time schedule, and cost considerations.

A fair amount of rigorous analysis can be attained by conscientious adherence to established relations between cause and effect in human matters. The social, political, and economic scientists should recognize these controls or cease to call themselves scientists. Often their half-truths, innuendos, and unrealistic conclusions have telling economic and functional impact on the serviceability of engineered facilities for which the design criteria have been impacted by significant influences rooted in environmental, social, political, and ecological niceties which may or may not be feasible. A statement credited by the Xerox Corporation to Joseph C. Wilson is apropos:

> "Organized human endeavor can be lifted an order of magnitude through leadership if it is inspiring. The springs of inspiration lie deep in the knowledge of all that is worst and best in men and in the wholehearted acceptance of that worst and best. To lead well is to know people and to know, above all, that they are always people. The roots of that knowledge are in the sturdy minds and noble souls of the centuries."

Adequate definition of the proper functions of the public and of the private sectors and assigning to each sector its proper role founded on rational analyses of cause and effect is necessary. Goals for environmental excellence depend upon such accomplishments. In addition, major progress toward excellence in the primary aspects of structures -- functional service, capacity to serve, time schedules, and favorable cost to benefit relations -- can be achieved through design excellence at little cost if such cooperative efforts could be pursued diligently in serious manner. One must realize that the leverage of such possibilities is great. Good and thorough design need be only a really small portion of the cost of a structure; but the savings and benefits of good design as reflected in the construction, operation and maintenance costs are many times greater than total design cost.

Structural engineers have a particular responsibility to frame the relevant influences of their expertise in form understandable by non-technical decision makers and, further, to see that the message is received. Talking about costs is a good way of getting the public's attention.

Cost considerations related to serviceability and maintenance include:

- Money for the physical creation of the project
- Environmental and community impacts
- Resource utilization
- Money for operation and maintenance throughout the life of the project.

The direct money values are readily arrived at once a definitive master plan and time schedule are actually adopted and frozen.

The environmental and resource factors are not yet susceptible to such specific determination, as has already been cited, being founded more on learned opinion than on evident fact. Here each critic, self-appointed or official, measures the impacts with his own elastic tape measure. Until such time as such critics resolve to work in the public interest instead of to show how smart they are, the reaching of the necessary mutual decisions will continue to be difficult.

In the transition, it can be demonstrated that any lack of adequate consideration of environment and of resources in the past was as much dictated by statute and criteria of owners emphasizing money economy as it was from neglect of the design professions. More recently, the criteria of owners, particularly government, have swung to the other extreme, practically ignoring money economy and timely design and construction. This brief recital of responsibility is solely for the purpose of emphasizing that the arrival at satisfactory design criteria with respect to the primary aspects of the structure and with due regard to all types of economy is a multidisciplinary responsibility. In the interests of true efficiency and economy the needed understandings, decisions and agreements should be reached expeditiously with adequate recognition of the state-of-the-art rather than requiring that one group propose and another denounce thus causing a long and wasteful iteration. Perhaps a lesson can be taken from the arts. Music, art, and drama critics are seldom successful composers, artists, playwrights or performers. Similarly, the public should recognize that the critics of structures usually could not themselves do the work of the creators in economical and useful manner. However, no one is perfect and informed constructive criticism can be very helpful.

Almost any structure or facility of significant proportions is a complex mechanism. Each aspect is interrelated. Changing design criteria will change all aspects to greater or less degree. That is why it is practically impossible to discuss any one aspect in isolated manner. For example, almost everything done affects cost, maintenance, and serviceability in some way. Costs accumulate from the time of initial thought of conception of a structure until the time it is no longer used, requires care, nor influences the environment. The sum total is referred to as life cycle cost. The subject merits mention in the context of serviceability and maintenance.

In passing it is observed that services which have been provided by a structure may still be needed even after the structure is 100 or more years old and has outlived its efficient usefulness. In such case, demolition and replacement costs enter the picture. This is a common event in the industrial and manufacturing areas and the result is more visible because it happens within a short time for many items of equipment. In the field of structures the time cycle is usually so great and the future social, political, and economic climates so uncertain as to make such consideration at the time of design of little merit in any way other than to amortize the cost of the structure being designed. In the same way, neither the design engineers, the owners, nor anyone else can peer into the future and focus on the route the economy and the style of living will follow. Therefore the usual practice for structures is to assume that economic, social, and political climates will retain their characteristics except that population growth and distribution, industrial growth, tax increases, and inflation will continue their historical movements.

The relative weight of life cycle cost elements will be quite different for different structures. All of the primary aspects of a facility are involved and to some extent can be varied to suit the owner's convenience and purposes. For example, initial capacity can be kept low with provision for expansion as the future may require within a range of alternates. Thus initial construction costs can be decreased while future costs will be increased, probably by more than is initially saved. Even so, there may be perfectly valid reasons for such a course.

This paper will not attempt to become specific in such matters. On the other hand most of the various elements will be present in nearly every case. A look at the forest will be helpful. Individual engineers will need to establish their own specific parameters for their own separate projects. In doing so they will give due consideration to the fact that governments often erroneously ignore certain cost areas such as rent, interest, taxes, administrative costs, fringe benefits for employees, insurance, and general overhead. Nevertheless such cost elements are important long-term cost factors especially when comparing alternate solutions, including public vs private sector participation, to arrive at the master plan. Such cost factors don't just go away even though they may not show in the departmental appropriation. The people still pay for everything they get; and sometimes for what they do not get.

For illustrative purposes the following partial list of cost and benefit elements which enter into life cycle evaluations will suggest the breadth of that approach to consideration of the five primary aspects of a structure with respect to return on the investment in terms of services and maintenance:

(A) Surveys and projections to determine character and magnitude of existing functional needs and their future growth rates;

(B) Preliminary studies and planning prerequisite to defining the master plan through analyses of alternates for the structure, including the design criteria and provisions, if any are needed, for future growth, relationships betwee time schedules and costs, analyses of environmental impacts, costs and benefits, and impacts on the economy of the community local to the structure;

(C) Feasibility studies to compare (a) estimated long-term benefits to be received as the result of services to be provided by the new structure as contrasted to existing ways and means with (b) the estimated expenditures required to provide, operate, and maintain the new structure and abandon the old one, if any exists, as contrasted to maintaining the existing facility. These estimates should be detailed rather than lumped into large units. Such practice will assist accuracy and facilitate understanding by the decision makers of comparative advantages and costs, of alternate possibilities for various parts of the structure as well as for the whole structure, and with respect to phased construction as needed rather than providing capacity for future growth at the outset;

(D) Financial planning and funding; including interest, amortization, debt service functions performed by trustees, lawyers, and consultants;

(E) Obtaining permits and other required authorizations;

(F) Hearings, reviews, audits, and similar checking operations which interfere with productive efforts;

(G) Final design and completion of all construction contract documents;

(H) Site selection and acquisition, including all associated secondary items;

(I) Legal fees;

(J) Accounting and auditing costs;

(K) Insurance of various types, including all risk, liability, workmen's compensation, health, unemployment, loss of use and occupancy;

(L) Administrative and management costs of owner's staff;

(M) Resource use and preservation;

(N) Construction and inspection of construction;

(O) Interest earned on unexpended fund balances;

(P) Interruption of on-going operations during construction, including inconveniences to others as well as to owner;

(Q) Salvage values of discarded existing facilities;

(R) Start-up costs, including operating manuals, selection and training of operating personnel, accumulation of inventory, and shake-down trials;

(S) Taxes and/or loss of tax ratables;

(T) Operation and maintenance including staff, equipment, materials and supplies, energy and other utilities, overhead, depreciation, and demolition.

A truth too infrequently appreciated in the initial concept stage, long before tangible details can be determined on a reliable study basis, is that some of the most important and far-reaching decisions with respect to serviceability and maintenance are required at that stage. In the absence of specifics, these decisions must be based on the judgment of experts trained by experience as well as in theory. Such judgments must reflect an awareness of local pertinent factors and influences. Examples of such early questions are: does the project appear feasible to an extent warranting careful exploration; what goals and objectives shall be established for the project; what is the order of magnitude of the costs and of the benefits over the years and how are they distributed over the time span; which of two or more projects should be selected when financial resources are limited; what time frame should be established; is it best to start with a low estimate or a high estimate of cost; is it better to organize for high initial rate of cost to gain low annual costs subsequently or vice versa? Many such questions could be more precisely resolved after extended study (and expense therefor) but practicality precludes endless study. The number of alternates to be investigated must be kept to a reasonable maximum even though for the usual structure these study costs are a miniscule portion of the total cost.

The key to this aspect of service with economy is a combination of theory, experience, and judgment. Hence the need for accumulated reliable data of benefit to every one, most particularly the ultimate consumer. Another requirement for coming up with the best solution to the continuing questions and problems is to pick the best qualified project corps at the very beginning and then keep it as it gains additional useful experience with the specific project and the manner in which it has developed. Such a life-line should flow through a job from concept into routine operation and maintenance long after implementation of service. Accumulation of written data cannot replace the human element in such cases.

It will be very helpful to develop a system of life cycle evaluation utilizing a universally understood terminology and viable methodology. Only in such manner can accumulated experience be intelligently applied. To emphasize the need for this universal language of communication between all parties concerned (owners, users, bankers, lawyers, designers, government) it is only necessary to recall the wide-ranging concepts now in use for one secondary cost element, namely overhead. Differences on the order of several magnitudes result from differing definitions which in turn affect evaluations of other elements.

It should be kept in mind that we are not here speaking of some new device. The experience of the authors includes evaluations similar to those being discussed on a wide variety and size of projects over a period of twenty-five years on facilities for which the aggregate construction cost has been several billion US dollars. The results have been remarkably good. It is significant that most of the projects concerned could not have been built without such analyses.

Approval of budgets and accomplishment of financing in timely fashion are more readily and economically accomplished for any projects if the rigorous feasibility procedures perfected for revenue bond projects are followed, thus providing independent certification in formal manner for all the engineering, legal, and financial data including purposes to be served and estimated return on the investment.

A cash-on-the-barrel-head-type of revenue supported financing through private channels has been used over many years very successfully for a wide variety of public projects, e.g. highways, bridges, airports, power generation and distribution systems, water supply and waste disposal systems. Not very different procedures have served for business and commercial projects, e.g. office buildings. The authors are convinced that the public interest would be served in additional public works projects, including structures, if similar rigorous procedure could be applied. Benefits to accrue could include elimination of unjustified projects, and establishing reasonable priorities for needed projects.

Engineers have a responsibility to encourage use of such supplements to their technical services as a means of providing needed services at reasonable cost for the benefit of the public. The best part about such improvements is that everybody benefits, including the engineers. Not the least of his gains will be improved stature and respect for this work.

At the same time, owners have a responsibility to realize that adequate evaluations for the primary aspects of a structure or project cannot normally be made until after (a) designers have had time to develop mutually with the owners full definition in technical terms of functional services to be provided by the project; (b) the designer has studied various alternate solutions and acquainted the owner with the results to an extent sufficient to convey full understanding thereof; and (c) both have agreed upon the characteristics of the master plan to be finalized. Meaningful life cycle evaluations cannot be made in casual manner and are not an exact science. They must be done with care and developed in an atmosphere of mutual confidence.

In recent years there has been a spate of novel procedures suggested by administrators as panaceas for too costly structures, taking too long to build, and not meeting desired service requirements when finished. That such difficulties have existed is true but the usual cause has been violation of the basics set forth above. The suggested cures do not treat the causes of the disease: insufficient authority at lower levels of administration, incomplete planning, inadequate design criteria, decisions made too late and changed too often.

The odds favoring thorough planning, adequate design criteria, and efficient management during planning, design, and construction are much too great to ignore. The time and cost are far less than for mediocre analysis and design; the resulting serviceability far better. The most complete and expert services in this stage cost but a small amount of the total life cycle cost and they exert a powerful leaverage on the remainder. The actions required of the owner to reap such benefits are not difficult; they are within easy grasp. Structural engineers can assist the owners in achieving desirable goals and have a responsibility to do so. After all, it is the results of engineering work that can make the difference if given appropriate opportunity.

Government has a unique responsibility in connection with serviceability and maintenance of structures. These aspects are influenced, sometimes even controlled, by building codes, zoning restrictions, and inspection procedures promulgated and administered by government to protect and benefit citizens. Today, these controls as they exist and are administered, frequently prevent the project corps -- owner, design team, builder, and user -- from achieving optimum results. The controlling documents are usually seriously out of date. The administration of the requirements is often by persons having insufficient knowledge and very little authority except in the negative. Any serious attempt at constructive progress via such controls is a rarity. It can also be observed that deliterious influences stem from selfish demands and restrictions sponsored by labor and by materials producers with the consent of government. It makes no difference whether that consent is in the form of silence or endorsement. Unfortunately the political well being of elected officials and the achievement of maximum benefit to cost ratios for public structures often appear incompatible when viewed solely in the context of the moment as contrasted to the long-term public interest.

It is certainly true that what has been accomplished in the past with structures in spite of all difficulties is very commendable and considerable. All concerned can take justifiable pride. Nevertheless, no human ever did anything perfectly. What could be accomplished would be unbelievable if all parties concerned cooperated constructively in full accord with the state-of-the-art with respect to life cycle evaluations of functional service, capacity to serve, environmental effects, time schedules, and cost to benefit relations. Serviceability and maintenance would be greatly improved and our structures would cost very much less. The public would be well served.

A major step forward in improving serviceability and maintenance of structures should be made by engineers taking the initiative to improve communications between owners, designers, builders, and users on a multi-lateral basis. Improvement of mutual understandings of the needs and problems of others could accomplish wonders. As one example of great opportunity, structures to house adequately a large proportion of the peoples of the world are prime candidates for such progress.

SUMMARY

Serviceability and maintenance are generally treated in the context of a systems approach during formulation of design criteria, master planning, design and construction. Emphasis is on continuity of considerations, need for achieving thorough mutual understandings between owner and designer, and flexibility and importance of cost-benefit relations.

The conclusion is that in many cases improvements at relatively small cost are a reasonable possibility.

RESUME

La serviciabilité et l'entretien sont en général pris en considération dans l'approche globale d'un système, lors de l'établissement du cahier des charges, du projet général, du projet d'exécution et de l'exécution. L'accent est mis sur la nécessité d'une analyse permanente et d'une collaboration totale entre le maître de l'oeuvre et l'ingénieur. Les relations coûts-avantages doivent être prises également en considération.

Dans de nombreux cas il est ainsi possible d'apporter des améliorations pour des coûts relativement faibles.

ZUSAMMENFASSUNG

Nutzung und Unterhalt werden im allgemeinen in einer gesamten Systemstudie betrachtet, sei es während der Festlegung des Pflichtenheftes, des Vorprojekts, des Ausführungsprojekts oder der Verwirklichung. Die Notwendigkeit einer permanenten Analyse und einer totalen Zusammenarbeit zwischen Bauherr und Ingenieur wird unterstrichen. Eine Studie der Kosten-Vorteile Beziehungen ist ebenfalls aufgeführt.

In vielen Fällen ist es so möglich, Verbesserungen zu relativ kleinen Kosten anzubringen.