Role of Research in Engineering Projects

By

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The Symposium today is on "Planning and Execution of Engineering Projects in Pakistan" and the particular aspect of the above subject on which I am called upon to speak is 'The Role of Research in Engineering Projects.'

Engineering Projects and Need of Research

In a progressive new State catching up with the advanced nations of the world, Enginneering projects have a very important place in the programme of national development. Most of West Pakistan being an arid zone, its agricultural economy entirely depends on an efficient irrigation system. Engineering projects in the field of Irrigation have, therefore, been receiving a high priority in the National Planning and will continue doing so. No wonder, therefore, that West Pakistan posseses the largest irrigation system in the world. The Sukkur Barrage System, the Triple Canal and Sutlej Valley Canal Systems, have no parallel even in the most advanced countries of the world.

There are yet other fields in which Engineering projects have to be planned and executed in order to make full use of resources endowed to the country by Nature. The Engineer has to harness the energy of the flowing rivers at all possible sites, to reclaim the deserts and waterlogged lands, to protect lines of communications and cities from the revages of devastating floods, to improve the waterways, the railways the highways and the harbours.

In planning and execution of the nation-building programmes he is called upon to dam, dike, divert, dredge and drain the mighty rivers or seas. He has to build huge structures on sand or treacherous clay or on rocks with faults. Very often in the design and execution of these projects, he has to take calculated risks where millions of rupees are at stake. The decisions at times are hard to make as the variables involved

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are very numerous; too often the mathematical solutions are not possible, the design practice, is either too costly or not fully applicable and the good judgement of the experienced designer needs a convincing support to take a final decision. It is here that an Engineer engaged in the design or execution of a project seeks the help of a research laboratory.

Research—its Branches and Scope

Before discussing the role of research laboratories in the Engineering projects, it seems essential to define and explain the term 'research' and its scope. Research is defined as diligent enquiry or examination in seeking facts or principles. It is laborious and continuous search after truth. The term 'research' generally includes all the categories of scientific and technical endeavour comprising "Pure Research", "Applied Research" and "Development." The pure research means seeking after new knowledge which is motivated exclusively by scientific curiosity and is independent of any idea of material gain by its sponsors. The basic and technical research fall within the domain of applied research. The basic research aims at 'why' and technical research on the 'how' of a thing. Development is the enhancement of design by the addition of practicability. This is an Engineering process slightly different from the work of design engineers. It consists in testing of new designs or procedures produced by research under actual field conditions to discover the omission and difficulties and then recommend correction. It is a follow-up for research and without development, applied research becomes sterile. Pure research is mostly done at the Universities with the support of foundations or philanthropists but applied research is almost always done in Institutes attached to industry or a large Engineering organisation where new problems are constantly cropping up for solution.

Development of New Research Techniques for Tackling Engineering Problems

In the years past, the Engineers and Scientists have developed new science and technique of model studies to investigate problems of Hydrodynamics and Aerodynamics. A new science of Soil Mechanics dealing with foundation problems of structure has come into existence and modern developments in Physics have given us new means of studying engineering problems by the application of electrical analogy and use of radio isotopes ; modern electronic instruments afford us meas to measure rapidly

fluctuating velocities and pressures giving better insight into flow phenomena and photoelastic methods having made it possible to study indeterminate stresses. Vast new fields of approach have opened up in the last century whereby engineering problems can be better studied in the laboratories.

Development of Model Science

In the past, for the solution of different problems of flow of liquids and of motion of bodies through fluids, two different approaches, namely, that of classical hydrodynamics and of hydraulics have been adopted. In the hydrodynamic approach, the mathematician deals with the ideal fluid, but the water with which the Hydraulician has to deal is not a perfect fluid, and the problem confronted by the Hydraulic Engineer are not capable of rigorous solution by the mathematical principles of Hydrodynamics. The Hydraulic Engineer, as a practical man, followed the empirical approach and used constants and co-efficients to fit the observed data and thereby produced working rules and formulae. Such co-efficients being of omnibus nature were supposed to take care of all known and unknown factors. The development of Hydraulics in fact started with what is called "vain motions and blind experiments." Thus Leonardo da Vinci in the fifteenth century studied flow phenomena and illustrated eddy motion, waves and jets and flow on weirs and through orifices. In the eighteenth century Dubuaght the French Hydraulician, carried out series of experiments on flow in pipes and channels and resistance of immersed bodies. His experiments demonstrated that the form of rear of a body is as important in controlling resistance as the form of the front. An era of experimenta! Hydraulics was thus started. Darcy and Bazin in late 19th century made use of first flume 1476′ long, 6·5′ wide and 3·12 feet high to study the effect of roughness of conduit surface on the loss of head by friction. The last 30 years of the 19th century saw the development of three experimental techniques for small scale testing which has continued to play leading role in the present day laboratory practice, one involved the wind tunnel, another the movable bed river model and a third a towing tank. Otto Lilenthal (1848-96) first measured the lift of an inclined plate on a whirling arm and Friedrich Phillips in 1884 devised and built a small wind tunnel in which he measured lift and drags of cambered vanes. Fargue gets the credit of constructing and testing first river model of Garonne river in 1875. His model was made to 1/100 scale and depth

and time scales were arbitrarily chosen. Osborn Reynold in 1855 for the first time constructed and experimented with a tidal model of River Mersey on properly corelated scales, The main contribution in initiating of towing tank technique is that of two Englishmen William Froude (1810-1879) and his son, Robert Froude (1846-1924).

These three sets of experiments were the origin and fore-runners of modern Hydraulics and Fluid Mechanics Research Laboratories, Naval and Towing Tank Researeh Stations and Aerodynamical Researches in wind tunnels. Today, these have extensive part to play in solving different Engineering problems in the fields of Hydraulics and Hydro-dynamics in the ship building industry and in Aerodynamical Engineering.

It is not the purpose of this note to deal with the history of the development of model science nor with the laws of model simlitude, but a brief outline of this development was essential to understand the transformation of approach to the study of problems that have since occurred due to the methods of model testing. The rapid developments in aeronautics and other hydraulic flow problems forced the leaders of thought in the subject to change the approach for study of such problems from purely empirical approach to that of physical phenomenon of flow. For example, in the past it was enough to determine the co-efficient of discharge of a spillway, an orifice or a weir, but it is no more sufficient. It is now essential to keep the boundary geometry of the structure in view, to think of the profile over or through which water has to pass at very high velocities ; a small error may cause cavitation, destructive pitting action and vibration, etc. Determination of detailed pressure distribution to avoid zones of separation and regions of cavitation is essential. The quest for speed, and tackling of ever-increasing discharges and ever-rising velocities have made model studies essential pre-requisite of any project. Therefore, with the modern stringent demands of aeronautics the "vain motions and blind experiments" of Hydraulics have slowly and gradually changed to fluid mechanics with model experiments as a major tool to study and solve the problems of flow and of resistance of partially or wholly immersed bodies. The result is that very high dams and high velocity water tunnels have become possible, large naval vessels and sub-marines have appeared and we have entered into the jet age.

Past and Present Method of Hydraulic Research

Some one can say that prior to the method of research by model investigation, we were training the rivers, constructing the weirs, building small dams, ships and harbours then why all this fuss about models. We learn from our experience on actual works, but it may be equally true as Melbourne said, "No-body learns from experience, every-body does the same things over and over again." In fact, formerly the knowledge and confidence for designing new works were generally obtained from previous experience. Francis Spring—the eminent engineer—while justifying the need of research in river problem to the Government of India has very aptly decribed the old full scale trial and error method by saying "Engineers have gone on blundering benefitting rather by chance than by design, by the experience of their predecessors, and each considering himself lucky if he escapes disaster at the hands of the tremendous forces of Nature—amongst which some of the most potent, for good or evil, are the great rivers with which he has to struggle." Failures, no doubt, can teach us what we do not know but this method of learning is slow and expensive. Now just compare the rate of construction and size of projects of the two periods pre- and post-model science and you get the answer.

You would agree that modern tempo of rapid advancement in every walk of engineering is due to the modern methods of research and its major tool-the models.

Model and its Limitations

A hydraulic model is a scaled replica, built in laboratory, of the prototype which may be a river, a barrage, a training work, a harbour or a spillway. Sometimes, specially for river models, the horizontal and vertical scales have to be different. In fact, selection of a suitable scale is very important for the success of a particular model investigation. In the laboratory, cycles of floods or waves or tides, as the case may be, are generated to a certain time scale, water levels ere reproduced, movement of silt is simulated by injecting silt at pre-determined rate, adjustment model barrage gates are made, and the effect of corrective works or alterations in design is investigated. From the results obtained in the laboratory, predictions are made about the behaviour of the prototype in the field and

in this manner the designer and the constructor get an insight into the problems that the particular structure or an operation Engineer will face in the future. Often the model itself needs proving tests before it can give useful information about alternative designs or corrective works. Unfortunately, due to a large measure of success of models in certain fields, an impression is growing that all you need is to construct and run a model and you get quantitative answer to any engineering problem. This view is not correct. It is wrong to presume that all models give quantitative results. The truth is that in the hand of an experienced interpreter who knows the limitation as well as the use of his model, one can get a reliable forecast of the shape of things to come even in those cases where quantitative results are not obtainable.

Role of Research in Engineering

Broadly speaking, applied research in the field of engineering can play the following roles :—

1. Cure existing troubles and remove the shortcomings by substituting materials, methods of construction or engineering practice.
2. Reduce cost of materials, construction or production operation and maintenance.
3. Improve quality of materials.
4. Develop new uses of existing materials and processes.
5. Develop new materials and substitutes for existing material and processes.
6. Improve construction, design or manufacture technique.
7. Collect technical information leading to better understanding about materials, processes of designs, construction and operation methods.
8. Contribute to common pool of knowledge.

In this Symposium, we will mainly be dealing with applied research and its role in different branches of Engineering, with special reference to problems in the domain of—

1. Irrigation, Water Power, Hydrology, Flood Control and Drainage Engineering.

Other branches of Engineering, e.g.,
Highway Enginee,ing,
Structural materials, Foundation Engineering,
Hydraulic Machinery,
Military Engineering,
Naval & Harbour Engineering, and
Aeronautical Engineering.

Role of Research in Engineering Projects in the Field of Irrigation, Power, Flood Control, Reclamation and Drainage

In the above fields the Engineers of West Pakistan have completed a large number of Engineering projects. Two barrages on Indus, namely, Taunsa and Kotri and three link canals in one case with a syphon across the Ravi have been constructed since Independence and a third barrage on Indus at Gudu is at present under construction. Rasul, Dargai, Chichoki and Shadiwal Hydro-electric power stations have also been completed or are near completion, The planning, design and construction of these works have been almost entirely done by our own laboratories. For each major barrage, as many as 20 to 30 problems had to be studied in the laboratories during the planning, design and construction stages. Thus for Taunsa, studies were made for the orientation of the barrage, for protecting the barrage area surrounded by Coffer Dams from river attack in the floods during the construction period, for the dewatering of construction area, for the fixation of waterway and crest levels, for the alignment of guide banks, and for checking the performance of the barrage under different conditions of flow varying from worst retrogression to maximum accretion in river levels. Very extensive research work was done for the necessity of silt excluders and the most efficient design of a silt ejector, simpler in design and lesser in discharge extraction ratio as compared to that required by a usual type of ejector, was evolved as a result of research in the laboratory. The most difficult operation is the diversion of the river over barrage after its completion, which is usually constructed in dry. This operation becomes much more difficult when the minimum river discharge at which diversion has to be done is high. Taunsa and Gudu come under this category. The actual operation in the field has to be preceded by a very extensive series of experiments for the fixation of design, dimension and number of the cuts, location of the regulator and the most probable river

course at the time of the diversion. Permanent training works to obtain suitable river approach to the barrage have to be located at the end of all these studies. Apart from the work on the main barrage a number of designs of falls, cross-drainage works, etc., have often to be tested in the laboratory. All this work for Kotri, Taunsa, and Gudu has been done in the Irrigation Research Institute Laboratories, and has caused considerable savings in the designs evolved thereby. Now that we are embarking on a huge programme consisting of two major dams, five new barrages, seven new link canals having a total length of 388 miles with capacities aggregating to nearly 100,000 cusecs, research has to play a really important role, in siting the barrages, proposing various silt excluding devices, correcting the river approach, flood disposal and many other allied problems. It is a tremendous undertaking in the history of construction of this sub-continent. Expansion of the laboratories and field research stations may be needed to cope with demands for these works, which have to be met with speedily, It is even desirable to appoint a Research Consultant who can help in guiding specialised types of work. This will not only increase the working potential of the research organisations and its personnel, but will enhance the 'know-how' of the staff and will provide independent check on the design. Already two Consulting firms, *viz.*, Messrs. Binnie Deacan & Gourley London and Messrs. Coode & Partners are getting work on diversion tunnel of Mangla and link barrages done from our laboratory.

Role of Research in Projects in Other Branches of Engineering

Research can play an important role in studying and solving special problems of the country in the field of Highway Engineering and cheap house building projects. In high water-table areas unequal settlement takes place and the roads get warped. Specifications for cheap village roads and effect of rise of salts on roads and foundations of the building are some of the urgent problems which are receiving attention. Research in economising cement by use of pozzolana such as surkhi as admixture have been carried out in Irrigation Research Institute and Buildings & Roads Research Laboratories and specifications have been laid for this admixture. This will not only affect 10-20% saving in cement but will have less heat of hyderation, better sulphate resistance and will give greater strength too. The actual use of these admixtures has not as yet become common because the

research has not been followecd up through the mill of Development(testing of new designs produced by research) which is essential procedure in complete meaning of Research. As stated before, Research becomes sterile if it is not followed up by development. Anyhow research, in these problems is being carried on in the laboratories of Buildings & Roads Department, and whenever necesssry in the Irrigation Research Institue Laboratories too.

In the field of sanitary Engineering, there are problems concening water conveyance, water pollution, peculiar problems of sewerage in our country, hygenic and cheap disposal and use of human and animal refuse. These problems are not receiving proper attention which they should. Research in the domain of public health should be vigorously strengthened if sanitary and public health conditions of the country have to be improved.

In the field of turbo-machinery as far as design of turbinees and pumps is concerned, no research is being carried out at present. The manufacture of centrifugal pumps has recently been started in this country but the size and type manufactured is based on typical designs already standardised. The need of further research exists and will develop as the industry expands. In fact Hydraulic Research plays an important role in the field of turbo-machinery. The design of turbine and pumps are tested very thoroughly as a small error in the curve of the blades or casing can cause cavitation and vibration. The determination of detailed distribution of pressure to avoid zones of separation and region of cavitation is essential. The quest for speed and tackling of greater discharges and higher and higher velocities have made research essential for such machinery. This aspect will have to be considered in time by the manufacturers who are taking up works in this line and research facilities will have to be provided in the country before the industry can manufacture machines answering to world standards.

A large number of tubewells have already been installed and many more are being inslalled, and the problems arising therefrom need a very thorough investigation. The most efficient working of the tubewell, the best and the cheapest type of strainer in relation to aquifers and yield and its life are questions on which huge amounts and success or failure of the projects in ground-water development depends. Very recently work

done in this Laboratory has shown how the yield from the pumps already installed deteriorates repidly with time and how the efficiency of tubewells can be increased by using multiple strainers, The dewatering of foundations is being done according to the proposals finalised by the laboratories,

In all advanced countries of the world, research is playing an important role in different military and naval projects of engineering nature. Researches in connection with motion of ships in fluid media, river control, improvement of navigation, construction of artificial harbours, flood forecasting, flood wave dynamics, artifical flooding & Hydrographic surveys find their application to different problems of military engineering. In the field of naval engineering, the hydro-dynamics of ship design, computation of wave resistance of under water bodies, under-water explosion and explosions near the surface in the vicinity of targets are some of the problems which Engineers of all advanced countries who are engaged in planning, designing and executing independently the projects of war and peace are undertaking. Laboratories can also play very important part in the problems of harbour improvements, sea-water damage, protection of harbours from tidal waves and hurricanes, best alignment and design of break-waters and navigation piers and protection against beach erosion, etc. Some of these problems exist in our country too and not in distant future we will have to tackle them. Very recently cyclones have twice caused immense damage to the city of Chittagong and its harbour, the hamlets on the shores, and vast areas around. It is time the planners and designers think of these problems and solve them taking the help of suitable research organisations.

In short, the planning of the projects in different branches of Engineering have to include laboratories as an integral part so that solution of engineering problems in different fields are found and sound and econonomical designs are evolved and successfully executed at site.