V.3 MARCH 1992

JOURNAL OF ENGINEERING RESEARCH

The Journal of Engineering Research is Published by the Engineering Research Center Tripoli, Jamahirya

فهرس اللغة الانجليزية

CONCRETE TECHNOLOGY FOR DEVELOPING COUNTRIES THE NEED FOR RESEARCH AND DEVELOPMENT *

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ABSTRACT

The economie achievement since the second World War of countries resource poor but rich in intellectual resources is reviewed. It is concluded that although wealth, per se, is a useful commodity to promote and maintain a sound, broadly-based industrial development, it is not the most important ingredient. Many countries that have a paucity of natural resources, for example, are now leading the world in high technology development.

A case is made for the establishment of a Centre of Excellence for Concrete Technology somewhere in the Middle East. The need for and benefits from such action are identified. It is concluded that developing countries need to concentrate their resources in such centres to ensure world class activity in the sciences and engineering, the feedstocks of technological development.

INTRODUCTION

Intellectual capital is an essential ingredient for the technological advancement and economic growth of a nation. "The capacity of a nation to generate new ideas, to adapt to change, to innovate, to make the most effective use of its natural resources and to improve its productivity and international competitiveness are all critically dependent on educated citizenry"[(1)]. It follows that first priority must be given to the enhancement of a country's intellectual resource by improving the quality of education at all levels, by increasing investment in new ideas and by encouraging innovation in every sector of society. In fact, research and development (R&D), to a great extent, is the outcone of a motivated and skilled human resource working in such a climate.

This paper stresses the importance of human capital and the role of R&D in the development of a nation. R&D efforts in rapidly developing and the developed countries are cited and the current state of R&D in developing countries is reviewed. The paper focusses on the needs of the developing countries and a plan of action is outlined.

The first part of this paper reviews the general issues and problems facing a developing country attempting to optimize the contribution to economic development of its intellectual and financial resources. The second part addresses, as a specific case study, the problems facing concrete technology, in its broadest perspective and recommenders course of action, an example of what could be accoumplished in a number of areas of technology.

Part I
INTELLECTUAL CAPITAL AND ECONOMIC DEVELOPMENT

Intellectual capital is the most important asset a nation needs to have in place in order to achieve and maintain economic growth, enhance thı́ı́ı́uality of life of its citizens and atrengthen its cultural heritage. Interestingly, experience tells us that access to an abundance of high quality natural resources (i.e. wealth) does not seem to be either an essential prerequisite or any kind of a guarantee that world class economic and technological development will occur.

Japan is an overcrowded country the size of California. The Japanese inport almost every kind of resource from food and fuels to metals. The Japanese steel industry is entirely dependent on both imported iron ore and coking coal, yet the Japanese are the world's largest exporters of world class automobiles[(2)]. Germany, with its enormously successful and broadly based manufacturing industries, is also dependent on raw material imports. The Netherlands, Belgium, Italy and France are countries equally rich in economic terms but equally resource poor. It is notable that all of these countries were devastated during World War II. Obviously, their primary assets were skilled and motivated people and a well ordered and developed social system.

More recently, Hong Kong and Singapore have arisen as spectacular examples of rapid technological

* Proceeding of the 2nd international conference an concrete Technology for developing countries oct 1986-Tripoli

development in the total absence of natural resources. Taiwan and South Korea are also remarkable for their economic growth and success in the international market place; the latter is competing very aggressively with Japan in a number of major product areas. These examples illustrate that ownership and ready availability of on-shore natural resources, although very useful, are certainly not an essential prerequisite for the rapid technological advancement of a country[2].

Consider also the examples of Israel and the middle Eastern countries. Israel, like Japan, has almost no natural resources. Indeed, the land was largely barren three decades ago. Yet Israel has made astonishing progress during this period. Although it is acknowledged that Israel has been the recipient of a significant amount of financial and technical assistance from the western world, an even more important contribution has been the influx of skilled, well-educated middle-class immigrants. Conversely, other countries in the Middle East are richly endowed in natural resources, but they have failed to develop their domestic industries to any large degree. For example, despite its enormous wealth, Kuwait has nothing like the productive capital of a Hong Kong of Singapore. It is self-evident that "... historical evidence suggests that the key to economic development is human capital - that is to say skills, knowledge, and above all, cultural attitudes"[2].

RESEARCH AND DEVELOPMENT AND ITS FUNDING

Knowledge and R&D create new resources where none existed before. According to Ayres, "it is appropriate to think of knowledge as a king of alternative to cacapital, or and of capital. Figuratively, at least, science and technology have achieved the alchemist's objective of converting common materials to gold"[2(]. Simply, R&D is vital for the advancement of mankind.

Figures (I) and (II) identify the R&D funding of some of the technologically developed and developing countgries respectively, as a % of their Gross National Product (GNP). R&D expenditure of some of the developed countries is also shown in Fig. (I). In addition, sources and expenditure of R&D funding in the U.S., for the last decade, is included in Fig. (2).

Although there is no simple relationship between R&D expenditure and economic growth rate, nonetheless Figures (I) and (II) suggest that R&D expenditures in the developed countries far exceed, using any measure, the comparable expenditures in developing countries. Further, the quantum gap between science and technology resources of developed and developing countries is readily observed in the following statistics (not included here); (i) the absolute volume of funds earmarked for R&D; (ii) their volume as a % of GNP; (iii) the absolute and relative number (To the whole population) of R&D researchers and centres, and the average size of such centres.

In the U.S., it is estimated that the total R&D funding for 1986 will be about $119 billion; the current forecast is that the proportion of GNP spent on R&D will continue to increase over this decade, at it has each year since 1978[3]. In 1984, 2.7% of GNP was spent on R&D.

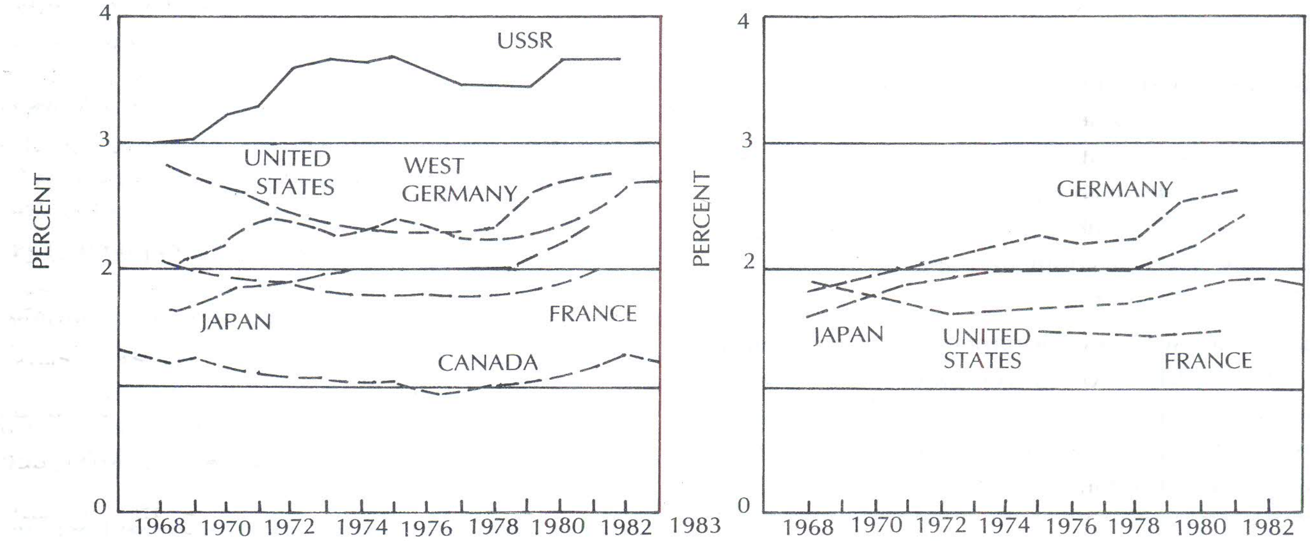

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Fig. I T&D EXPENDITURE AS A PERCENT OF GNP (I)

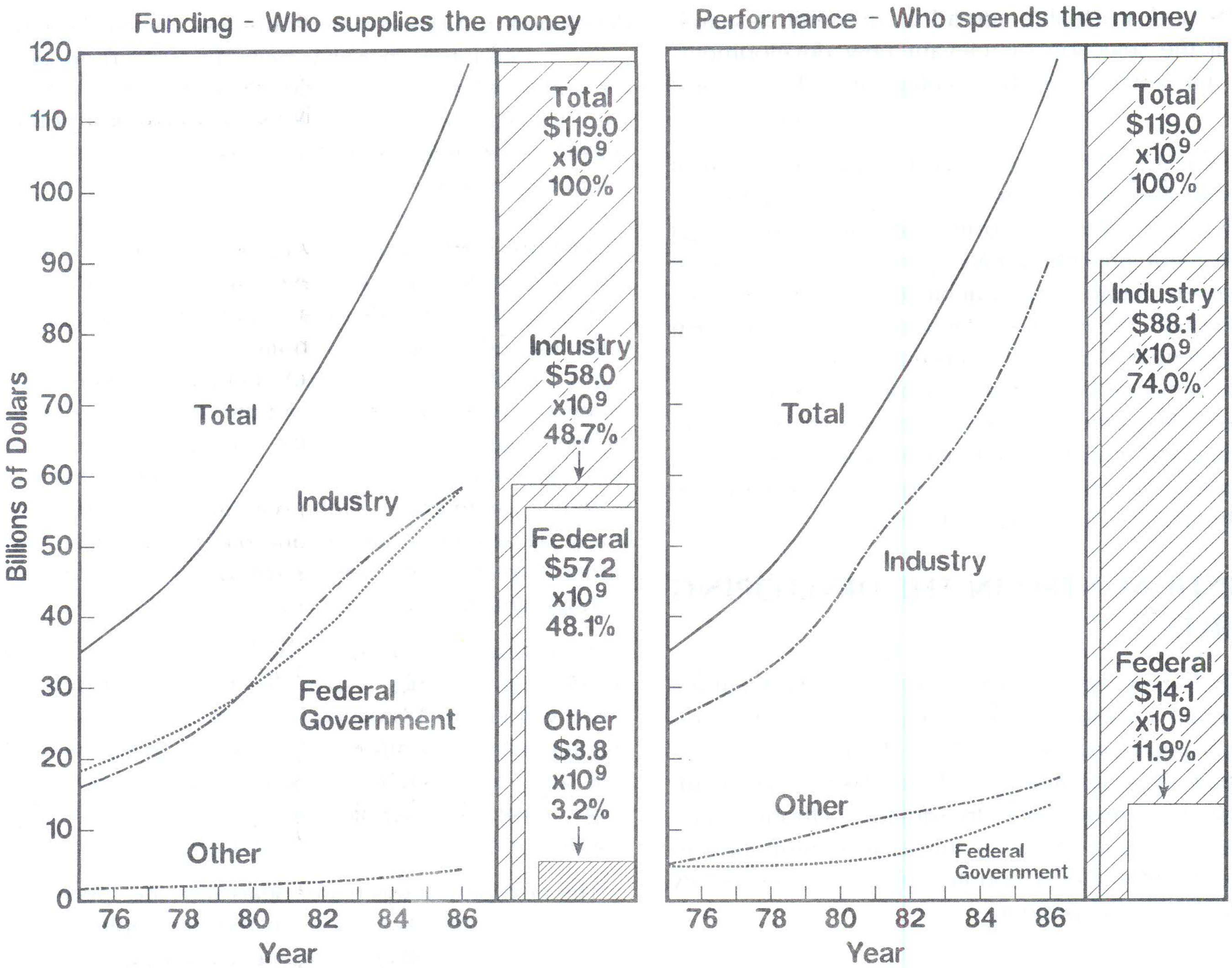

Fig. 2 R&D Funding and expenditure for the united states

ACQUISITION OF TECHNOLOGICAL CAPABILITY AND SOME PREREQUISITES

Technology can be defined as the art of transforming scientific and engineering achievement and discoveries into products. It is disaggregated into three basic elements: information about the method, means of using the method to undertake the transformation, and understanding how capability - in production, investment and innovation[5].

"The acquisition of technological capability does not come merely from experience, though experience is important. It comes from conscious efforts to monitor what is being done, to try new things, to keep track of developments throughout the world, to accumulate added skills and to increase the ability to respond to new pressures and opportunities"[5]. In summary, technology is not simply a product to be bought or sold. It is itself a means to an end. There are no magic levers to be pulled that will deliver technology overnight.

It can be argued that the diffusion of technology, mainly through the purchase of patents and know-how, can compensate for inadequacies in domestic research effort or indigenous innovation. The example of Japan, which started its successful industrial development based primarily on imported technology, dramatically illustrates this point. Uowever, it mmast be reaıoaed tjat effectove tramsfer pf tecjmpıpgu cam be reıoed upon in countriee-possessing and educational activity above a certain threshold[6]. According to King "Secondary or imported innovation, although not requiring a high level of R&D efforts as does the generation of new technology, nevertheless demands excellence in its education systems and a sizeable spread of domestic research effort if the selection of relevant new developments from abroad are to be intelligently chosen and assimilated"[7].

The OECD studies also suggest that a proportion of the technological innovation of a country aspiring to an advanced industrial position should be based on its own, not imported, R&D if real vitality is to be maintained. Japan, having achieved a level of economic strength on imported technology, built its own R&D potential in parallel and is now producing an impressive amount of original innovation[6]. In summary, domestically performed R&D remains important in reaching and maintaining competitiveness in growth industries and, where appropriate, in ensuring the speedy adoption of imported technology.

A CRITICAL NEED IN THE DEVELOPING WORLD

In the preceding sections we have observed that the intellectual resource, quality education at all levels and sustained endogenous R&D efforts, are essential to sustain the economic growth and technological advancement of any nation. In addition, although capital resources can make an immense contribution to the development of a country, it is not a necessary and sufficient component.

CENTRES OF EXCELLENCE

Clearly, such human capital needs access to and support from the best education available in a wide range of well-equipped and well-staffed post-secondary educational institutions. This implies that most of the developing countries should, within their resources, increase spending on higher education in a selective way with a view to supporting the development of a few world class "centres of excellence". A "centre of excellence" (CE) is defined here as any institution of higher learning or research with standing, recognition, and acceptance in the international research community. By definition, a CE should be able to attract both its faculty (or researchers) and students from anywhere in the world. Creation of these centres is neither a fantasy nor is it impractical. There are numerous such centres in North America, Europe and elsewhere in the developed countries.

"BRAIN-DRAIN"

"Brain-drain" is a well known phenomenon in both developed and developing countries. Oversimplified, countries there has been an over production (or under utilization, or middle level trained manpower. This has led, in national terms, to the loss of this skilled manpower through migration to developed countries or other more intellectually attractive developing countries. A second and more critical source of brain-drain is the expatriate higher education and training of scientists and technologists from the developing countries in the developed countries[8]. These foreign trained personnel, usually the brightest of the home country's scientists and engineers, present problems on their return home (if they return home!) due to their high expectations for research infrastructure and other related support. The net result is that the potential "seed grain" of the scientific communities of many developing countries in recent years has been underutilized upon their return or are lost forever through emigration.

It is envisaged that the establishment of CEs in some developing countries, especially those rich in resources,d will create a balance between 'brain-drain' and the retention and attraction of skilled manpower. It will serve to generate new knowledge and will promote basic and applied research relevant to the conditions and specific needs of a given country.

The next part of this paper deals with the specific issue of Concrete Technology in the developing countries,d a focus of this conference. Although the case study is very specific it will be clear that the same approach and philosophy would be applicable to a wide range of technologies.

PART II

A PROPOSAL FOR THE ESTABLISHMENT OF A WORLD CLASS CENTRE OF EXCELLENCE IN CONCRETE TECHNOLOGY IN THE MIDDLE EAST

CONCRETE TECHNOLOGY IN THE DEVELOPING COUNTRIES

Concrete is a universal material of construction. It competes with wood for housing, with steel for structures, with asphalt for roads, and with stone and earth for dams[9]. In many developing countries the presence of suitable raw materials favours the use of concrete structures. Aggregates are always available, although the quality may vary widely. Concrete, however, is an extremely variable material due to the inherent variability in its constituent materials, differing construction procedures and techniques, and the effect of the enormous range in ambient climatic conditions it is exposed to.

As concrete is a remarkably simple material of construction, it has often been abused, albeit unknowingly. Partly due to this and partly to changes in concrete technology such as the composition of portland cement, increased use of mineral admixtures etc., the durability of concrete structures has been compromised, sometimes dramatically. Consequently, the cost of repair and maintenance of concrete structures has increased many-fold in recent years the world over. It is apparent that in the future more funds will be required annually to maintain old concrete than to bullding structures, (It has been suggastad that some $60 billion are needed to repair and upgrade the highway bridge infrastructure in the United States alone).

The challenges to the cement and concrete industry in developing countries are numerous and often quite unique to the particular region. In the last two decades there has been a rapidly expanding and most demanding concrete construction programme in the Middle East. As an example, concrete technology and its practice in the Middle East is cited as a case study in this paper.

SOME UNIQUE FEATURES OF CONCRETE CONSTRUCTION IN THE MIDDLE EAST

Aggregates - The hos desert sediments and rock types are significantly different to those commonly met elsewhere. Good aggregates are generally difficult to find. The coarse aggregates, if not properly selected and processed, are highly absorptive, contaminated with salts and are dusty. Natural fine aggregates are also salt-laden, single sized and fine and composed of carbonate grains (beach type sand). Characteristics of these aggregates and problems associated with their use are well documented (10, 11, 12, 13, 14, 15, 16, 17).

Climatic and Ambient Conditions - Climatic and ambient conditions in the region are very severe and as a consequence concrete construction has experienced severe problems ranging from unsightly cracking to complete failure of buildings, Reactive minerals, the climate and water conbine to undermine the durability of concrete in this environment. "The root of the problem lies in the chloride and sulphate salts which pollute the ground, the wter, the atmosphere and the aggregates, which set up aggressive chemical reactions which break up the concrete. The extremes of climate accelerate both chemical attack and physical deterioration". Temperature as high as 50°C is common and continuous thermal expansion and contraction leads to cracking of concrete. High porosity or cracks in the concrete allow salts to penetrate which contribute to salt weathering. In addition, chlorides set up electrochemical reactions with the steel reinforcement which rapidly promotes rust. Clearly, the way in which ambient conditions affect the durability of concrete in these regions is rarely simple.

CURRENT DESIGN PROCEDURES AND CODES OF PRACTICE

The starting point in the construction of concrete structures is design, and design, most often, conforms to the prevailing National Standards and Codes of Practice. A code provides rules for the design and construction of a structural element and/or structure so that adequate strength, serviceability and durability are ensured. However, in most countries of the Middle East, local standards and codes are inadequate or non-existent. According to Soane[(19)]. "a code written with British aggregates in mind may not be appropriate to a poorly graded material dug from a pit in the desert. A standard specification clause intended to deal with light surface rusting of reinforcement will not be adequate for the deeppitting aggre- sali Simillarly, the high temperatures of the Middle East cannot be accommodated by standards developed from research and practice in countries with a temperate climate. According to Tobin[(20)], "most of the Civil Engineering firms working in the United Arab Emirates are European, and yet the type of construction required and the materials available are often very different from those in Europe. When engineers have tried to use standard European specifications in this different situation, problems have sometimes arisen". In summary, lack of appropriate codes of practice based on the performance of concrete using local materials in the prevailing ambient and other exposure conditions is a serious limitation to the advancement of concrete technology and ultimately the performance of concrete structures in these areas. Fortunately, many of the problems encountered with concrete work in the area are new widely understood and formulation of adequate local codes of practice is progressing satisfactorily.

NEED FOR R&D

From the preceding section we can conclude that concrete technology in the Middle East has faced, and will face, a host of challenges. These challenges are not unique; the concrete industry in the developed countries also encounters difficulties as the technology advances which require ongoing input. It is true that "domestically-performed R&D remains important in gaining and maintaining competitiveness in growth industries and in ensuring the speedy adoption of imported know-how[1]: A steady but sure way out of the current dilemma is the continuation of endogenous R&D efforts on the indigenous materials of construction under local conditions. In fact, R&D is capable of making important contributions to the achievement of higher quality, faster construction, greater economy and improved safety of structures.

According to Fookes et al, "much more research is needed on the effects of hot weather on the setting, hydration, hardening and aging of concrete, on the influence of salts on the above process, on the migration of salts in hardened concrete and on prevention and protection methods". The choice of suitable aggregates is v'v important and this choice must be aided by careful comprehensive testing programs. Accordingly, research is needed to help in the evaluation of aggregate quality, performance characteristics and to improve testing procedures. This research must be related to prevailing environmental and exposure consitions and to continuing developments and improvements in other fields of concrete technology.

CONCLUSIONS AND RECOMMENDATIONS

(A) GENERAL

1. R&D funding should be increased from the current very low levels, especially in resource-rich developing countries.

2. Establishment of centres of excellence should be given a high priority and the resource-rich developing countries should show leadership. Anticipated advantages from creating these centres are:

(i) The centres will attract world class faculty from the community. This will certainly add to the intellectual resource of these countries.

(ii) Excellent research facilities in these centres will encourage many local scholars to remain at home. Such indigenous post-graduate education and research opportunities will check the "brain-drain" and, in addition, will serve to attract international scholars.

(iii) Local production of scholars with advanced degrees will result in creation and dissemination of new knowledge within a country.

(B) CENTRE OF EXCELLENCE IN CONCRETE TECHNOLOGY

(iv) Indigenous research in such centres will provide opportunities to study and experiment with local materials under local environmental conditions. It will improve knowledge on the behaviour of local materials. This is important for an extremely variable material like concrete as some of the problems of the concrete industry are unique and singular to many parts of the developing world.

(v) Modern and fully equipped laboratories in these centres can be used for problem-oriented research; most of these problems will come from the construction and concrete industry.

(vi) The basic and applied research and testing conducted at these centres on the local materials and structural components will help. 22. Fookes, P.G. "An introduction to the influence of natural aggregates on the performance and durability of concrete". Q.J. Eng. Geology, Vol.13, pp.207-229, 1980.