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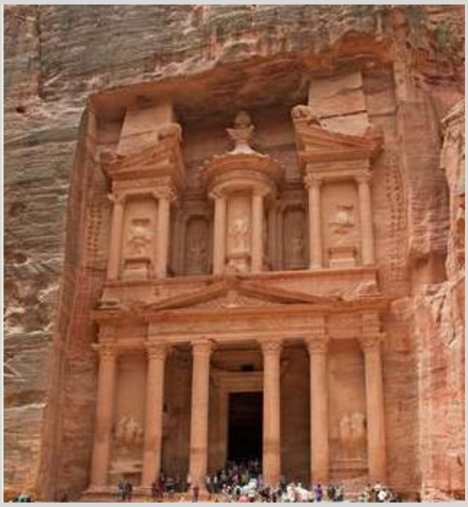
Cover Story

The State of Energy in Pakistan

Gerald Lacey – a brief biography



The Pakistan
Civil Engineer

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Editorial

The fifth issue of the Pakistan Civil Engineer is before the readers.

The main story for this issue is the energy situation of Pakistan. Hydropower potential of the country being its most cherished source of energy, the topic is as much of an interest for the civil engineers as it is for engineers of other disciplines. PCE feels that the PSCE readers would find the material useful, in providing a fact-based perspective to the issue.

Looking forward to feedback from the readers,

Rizwan Mirza
Chief Editor

Cover Story

The State of Energy in Pakistan

Rizwan Mirza
CEO, Rizwan Mirza, Consulting Engineers

Energy crisis hit Pakistan, the way few things did in the past, the energy crisis appears to have become a permanent feature of the national economy. Outages, burgeoning prices and circular debt are only few forms of the crisis that prominently feature in national discourse.

The electricity became common quite late in Pakistan. It has been suggested that when Pakistan become and independent country, it had a total installed capacity of 60 MW.

No wonder, the legacy of large ceiling-mounted and rope pulled *punkha* survived the Raj days to a very late period in Pakistan.

Figure 1: Large *punkha* suspended from ceiling and operated by a collie -- a legacy of Raj days

Automation was not slow to follow, but still without the use of electricity. English language newspapers regularly advertised kerosene fans for the elite. A clipping from one such advertisement shows how these kerosene *punkhas* were advertised counting advantages over collie-operated *punkhas*.

Figure 2: Kerosene fan advertisement by the Jost Co., which also manufactured electric and hot air fans. Image source: Antique Fan Collectors Association

DC Generation

In the early years of British Raj, only electricity provided was in important towns through their local direct current diesel generators.

One might refer to the Holy Bible, in respect of the basic roles of darkness and light in life:

> *And God said, Let there be light: and there was light.*
>
> *And God saw the light, that it was good: and God divided the light from the darkness*
>
> *Genesis: The Holy Bible*

Hydropower Years

In 1925, the governor of Punjab Sir William Malcolm Hailey, inaugurated the landmark 5-turbine, 1.1 MW, run-of-river power house, privately built by Sir Ganga Ram, and located at Lower Bari Doab Canal, in the town of Renala Khurd, District Okara.


Figure 3: The 1.1 MW Renala Khurd Powerhouse of Sir Ganga Ram

A decade after this, a run-of-river low head 1.7 MW hydroelectric powerhouse over River Sawat at Jaban (Malakand-I) was constructed, which was later upgraded to a 20 MW capacity, in 1948. Dargai (Malakand II) followed in 1953.

It has been reported that at the time of independence, Pakistan had a total electrical installed capacity of 60 MW.

The first 132 kv transmission line was commissioned in 1952.

In 1958, as the installed capacity of the country had increased to 119 MW, a new organization was created, under the name of Water and Power Authority (WAPDA). WAPDA was charged with the duties of: a) generation, transmission and distribution of power; b) irrigation and reclamation of saline and water-logged land; c) flood control; and d) inland navigation.

With the signing of Indus Basin Treaty in 1960, Pakistan was allocated the use of 142 MAF of water (Indus 93, Jhelum 23, and Chenab 26). As new storages were created, the hydropower capacity of the country began to greatly increase. Addition of the following hydropower facilities gave a qualitative boost to the installed capacity of the country:

Table 1: Early major hydropower facilities

	Description	Generation MW	Storage MAF	Year
1	Warsak	240	0.025	2012
2	Mangla	1,000	5.34	1967
3	Tarbela	3,478	11.30	1975

Some hydropower facilities added later include:

	Description	Generation MW
1	Ghazi Barotha	1,450
2	Chashma	184
3	Jagran, Malakand-III	30
4	Naltar	18

Thermal Power Years

In the 1995, the total installed capacity of power generation in the country stood at 10,563 MW while the gap between demand and supply had greatly widened due to burgeoning population and a good growth rate of national economy. The peak load shortfall, at that time, was estimated at around 2,000 MW. The then-government responded by introducing the 1994 Power Policy which invited investors to install power houses running on fossil fuel. The option of this expensive electricity was ostensibly adopted as a short-term measure, due to low gestation period of thermal plants. By 2002, the installed capacity of Independent Power Plants (IPPs) stood at 5,715 MW.

Long-Distance Transmission

Pakistan's system of electricity generation and consumption requires long-distance transmission of electrical power, across the country. As the electricity is produced, it needs to be transmitted and distributed, so that it can be utilised. Transmission voltages of 500 kV, 220 kV and 132 kV are the mainstay of the system. Distribution voltage is generally 11 kV.

Following data of the growth of transmission capacity has been obtained from NTDC's documents:

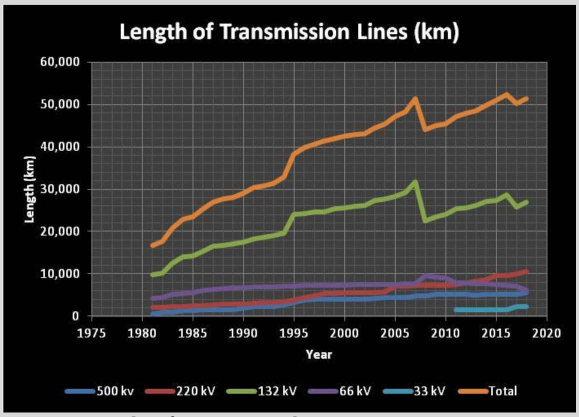


Figure 4: Lengths of transmission lines

Circular Debt

Circular debt in respect of unpaid bills of IPPs is a menace that has hit hard the national economy. While the power is purchased from IPPs according to metering system installed at these facilities. The government is unable to receive the payment against the amount of energy so purchased and is, therefore, unable to pay the IPPs. Due to unsound practice of complacence and failure to take timely rectification measures, the unpaid amounts pile up and ultimately reach a value when they become extremely large and are labelled as circular debt.

Some energy is claimed to be lost during transmission and distribution, in what are often called technical losses. Second loss is claimed to occur as the distribution companies (DISCOs) are unable to recover from their consumers the sums due against the energy received by DISCOs. The total figure of these two losses is euphemistically known as technical and distribution (T&D) losses.

Some of the claimed losses are arguably theft and do not stem from essential inefficiency of every process through which energy passes and partial losses inevitably take place. The fact is that the losses may be divided into: a) essential technical losses; b) inefficiency; and c) theft.

The data of Transmission and Dispatch Company (NTDC) shows the following variation of technical losses over the years:

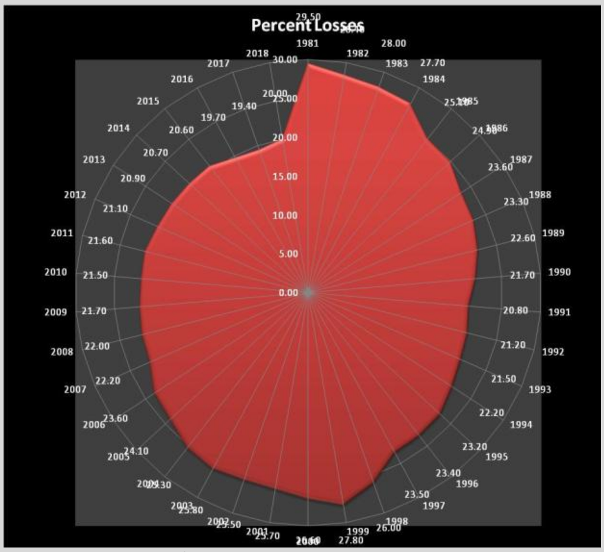


Figure 5: Variation of percent losses

A peak of 29.50% of loss has been registered, per the above data. The loss has been more than 20.00% in 94.74% of the years, more than 22.50% in 55.26% of the years, and more than 25.00% in 31.58% of the years.

According to National Electric Power Regulatory Authority (NEPRA), the target for of T&D loss for the financial year 2017-18 was 15.92% while the actually reported value of this loss was18.32%. Similarly, the recovery of DISCOs was at around 87.71%. The rest is simple arithmetic.

Consumers of Electricity

According to State of Industry Report, 2018, prepared by the NEPRA, following average sector-wise consumption pattern has been observed in the country between financial years 2013-14 to 2017-19:

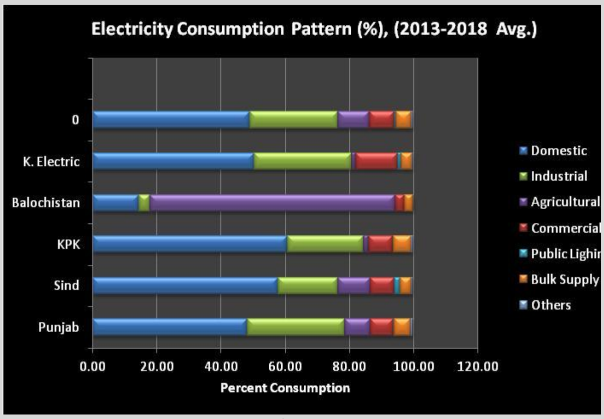


Figure 6: Consumption pattern of electricity in Pakistan

As may be noted, domestic consumers, followed by Industry, lead the demand in all consumption centres except for Baluchistan, where the first and second positions are held by Agriculture and domestic consumers respectively. But it must not be forgotten that that the total consumption of each province is not equal.

Current Energy Mix

According to data provided by the NTDC, Pakistan had a total installed capacity of 35,372 MW, in 20017-18. The breakdown is as follows:

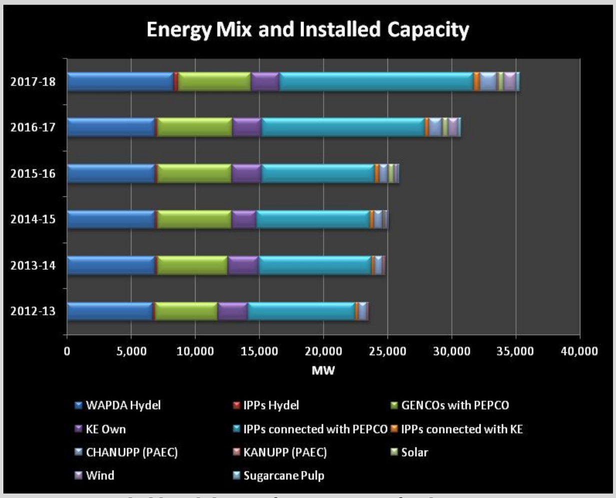


Figure 7: Detailed breakdown of energy mix of Pakistan

The above values show that the country's primary reliance on fossil fuel, for the generation of electricity, increased ever since the energy crisis assumed serious proportions. The following figure illustrates this point:

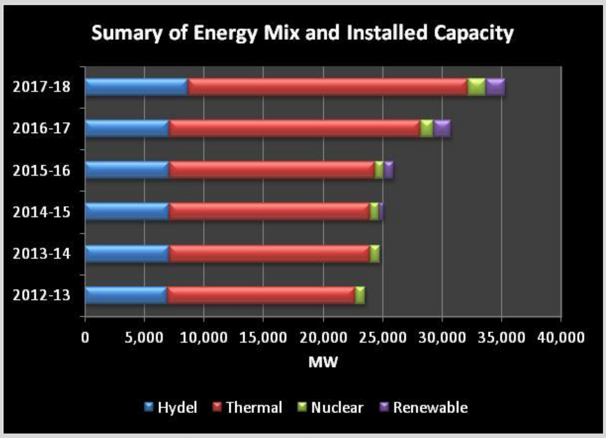


Figure 8: Summary of energy mix of Pakistan

The figure shows that in 2017-18, hydropower had around one-fourth of the national installed capacity while plants running on fossil fuel had around two-third.

According to NEPRA's State of Industry Report, 2017, the following additions, to the national grid, are expected to be made in the years to come:

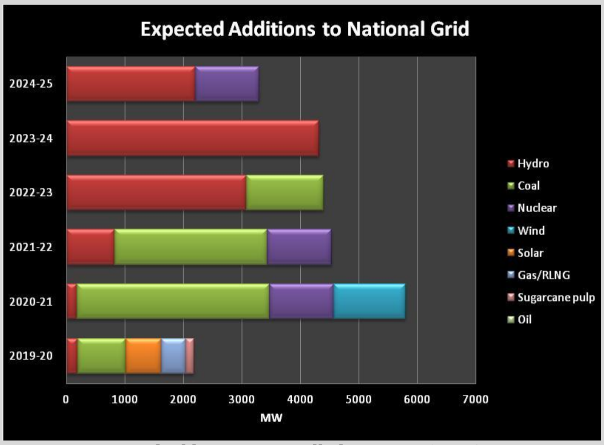


Figure 9: Expected additions to installed capacity (1917)

The present government has now initiated a policy under which a paradigm shift is planned, whereby major reliance would be placed on domestic resources, for the production of electricity.

Water Resources Projects – the key to Cheap Electricity in Pakistan

Muhammad Ashfaq Hanif
Senior Projects Manager, Saudi Electricity Company, KSA

Electricity is one of the prime movers of a modern society and its availability, reliability and cost-effectiveness remain the moot questions for an economist. Cost of energy in Pakistan affects the cost of production for our industry and, in an increasingly competitive world, keeping it down must remains a goal of economic policy.

If the GDP of a modern country is expected to grow, matching increases in electrical capacity are required.

Pakistan has a total generation capacity of about 33,000 megawatts (MW), of which about 9,000 MW is contributed by hydropower generation, while the rest is contributed by gas, coal, nuclear, solar or wind. Presently, the energy mix of the country is as follows[1]:

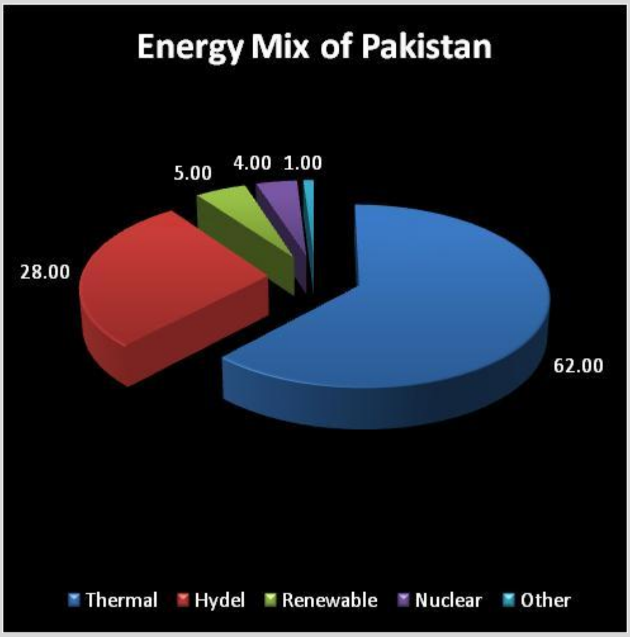


Figure 10: Energy Mix of Pakistan

With the commissioning of the 108 MW Golen Gol, the 1,410 MW Tarbela 4th Extension and the 969 MW Neelum-Jhelum hydropower projects, in 2018, the installed generation capacity of Pakistan Water and Power Development Authority (WAPDA) hydroelectric power surged to 9,389 MW from 6,902MW, registering an increase of 36 per cent in one year.

The hydropower power stations, owned and operated by WAPDA, generated the highest-ever electricity during peak hours in July, 2019 as WAPDA's hydropower generation crossed the 8,000 MW mark for the first time in Pakistan. As per generation details, WAPDA delivered as much as 8,158 MW of electricity to the national grid, during peak hours of July 31, 2019[2].

Arguably, hydropower is the cheapest and the most environment-friendly source of electricity. According to the data of Pakistan Electric Power Company (PEPCO), regarding per unit cost of electricity generated from various sources during fiscal year 2017-18 and 2018-19, it is Rs 2.22, for WAPDA's hydropower, which is far less than per unit cost of electricity generated from all other sources.

[1] The Express Tribune, Pakistan
[2] The Express Tribune, Pakistan

The cost of electricity from various sources is as follows[3]:

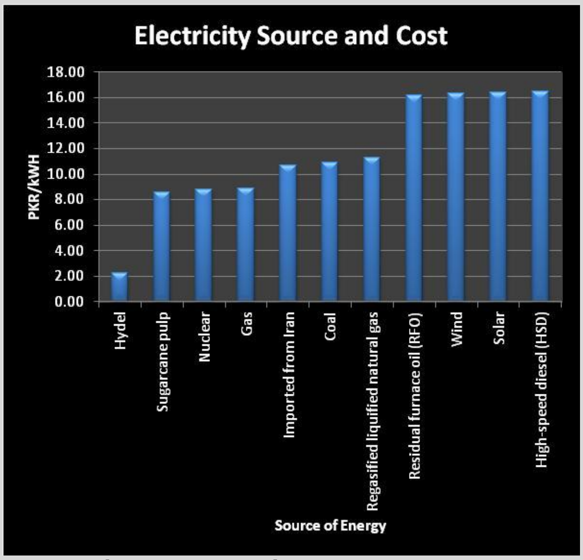


Figure 11: Electricity source and cost

Total Hydropower Potential of Pakistan

According to WAPDA, there is 60,000 MW of hydropower potential in the country, of which only about 10,000 MW has been developed. Pakistan's untapped hydropower potential largely lies in the mountainous north along the Indus River and its tributaries in the provinces of Gilgit-Baltistan and Khyber Pakhtun Khwa, as well as the Jhelum River and its tributaries in the provinces of Punjab and Azad Jammu and Kashmir by constructing the large and small dam reservoirs at these rivers.

The under-construction small and large water resources projects have a total capacity of about 8,000 MW and these projects shall be completed by 2025 to make the country's total hydropower generation capacity to about 18,000 MW.

A number of small and large dam projects are there for which the feasibility studies and detailed engineering design is completed and these projects are ready for construction. The total generation capacity of such projects is about 17,800 MW and if the construction of these projects is started any time in the next one to two years, these can be complete and operational by the year 2027.

Pakistan's hydropower generation capacity can, thus, reach up to 35,000 MW by the year 2028. The feasibility studies are under progress for about 6,500 MW capacity hydropower projects while the preliminary reports has been completed for another 10,000 MW projects. Some other projects of 6000-8000 MW are there for which the site selection has been done and ready for pre-feasibility studies.

Various approaches have been adopted for projecting the energy requirements of future. While the results of these projection may vary, the fact remains that installed capacity of power generation has to maintain an upward trend to match the target GDP growth for the country.

Concrete – Past, Present and Future

Muhammad Ashfaq Hanif
Senior Projects Manager, Saudi Electricity Company, KSA

Concrete (portland cement concrete), well known to all civil engineers, is a composite material composed of fine and coarse aggregate, bonded together with a cement paste hardens over time. It is arguably one of the most frequently used building materials.

In modern concrete, when aggregate is mixed with dry portland cement and water, the resulting mixture can be easily poured and molded into shape. Later, the cement reacts with the water and the mixture assumes stone-like properties. Often admixtures are also included in the ingredients in order to impart various physical properties.

Concrete is often used in conjunction with reinforcing materials (such as reinforcing steel bars), in order to form a composite material, which is called reinforced concrete.

Ancient Concrete

Small-scale production of concrete-like materials was pioneered by traders of Nabataea (Arab political state) who occupied and controlled a series of oases and developed a small empire in the regions of southern Syria and northern Jordan, at around the 4th century BCE. They discovered the advantages of hydraulic lime, with some self-cementing properties, by 700 BCE. They built kilns to supply mortar for the construction of rubble masonry houses, concrete floors, and underground waterproof cisterns.

[3] The Express Tribune, Pakistan

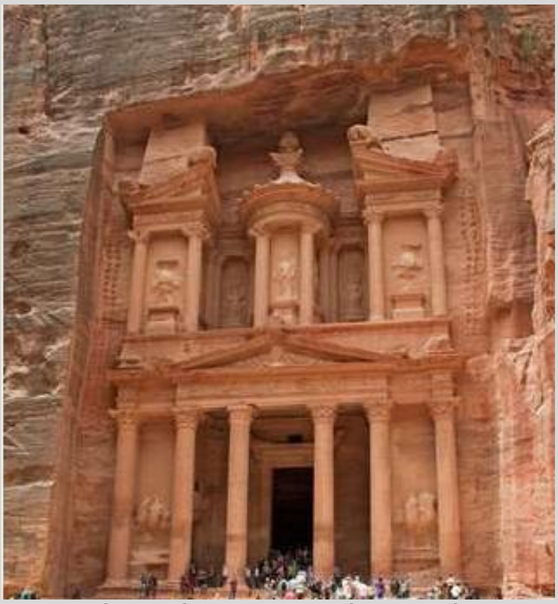


Figure 12: The Kasneh (Treasury) – a Nabataean tomb at Petra, Jordan

In the Ancient Egyptian and later Roman eras, builders discovered that adding volcanic ash to the mix allowed it to set underwater. Concrete – as the Romans knew it – was a new and revolutionary material. Lending itself to molding, and laid in the shape of arches, vaults and domes, it quickly hardened into a rigid mass, free from many of the internal thrusts and strains that troubled the builders of similar structures in stone or brick.

After the Roman Empire, the use of burned lime and pozzolana was greatly reduced. Low kiln temperatures in the burning of lime, lack of pozzolana and poor mixing all contributed to a decline in the quality of concrete and mortar. From the 11th century, onwards, the increased use of stone in church and castle construction led to an increased demand for mortar. Quality began to improve in the 12th century through better grinding and sieving.

Contemporary Concrete

Presently, concrete, that we are all familiar with, is produced in a variety of compositions, finishes and performance characteristics to meet a wide range of needs. Modern concrete mix designs can be complex. The choice of a concrete mix depends on the need of the project in terms of strength, durability, expected nature of exposure, desired means of pouring, required appearance and in the requirements of local legislation and building codes.

Weigh-batching and control of – or adjustment to – other parameters ensures the maintenance of a uniform level of quality.

The Future Trends

Ultra-high-performance concrete (UHPC) is a new type of concrete that has being developed recently by agencies concerned with infrastructure protection. UHPC is characterized by being a steel fiber-reinforced cement composite material with compressive strengths as high as 21.75 KSI (150 MPa).

UHPC is also characterized by the make-up of its constituent materials: typically fine-grained sand, silica fume, small steel fibers, and special blends of high-strength portland cement.

Micro-reinforced ultra-high-performance concrete is expected to be the next generation of UHPC. In addition to its high compressive strength, durability and abrasion resistance of UHPC, micro-reinforced UHPC is characterized by ductility, energy-absorption and resistance to chemicals, water and temperature. Micro-reinforced UHPC may be considered for blast-, missile - and earthquake-resistant construction, structural and architectural overlays, and complex facades.

Self consolidating concrete (SCC) is concrete which, when fresh, flows under its own weight and does not require external vibration to undergo compaction. It is used in the construction where it is hard to use vibrators for consolidation of concrete. Ability to freely flow and fill and resistance to segregation are some of the properties of self compacting concrete.

The stability or resistance to segregation of the plastic concrete mixture is attained by increasing the total quantity of fines in the concrete as also by using admixtures that modify the viscosity of the mix. Increased fines contents can be achieved by increasing the content of cementing materials or by incorporating mineral fines.

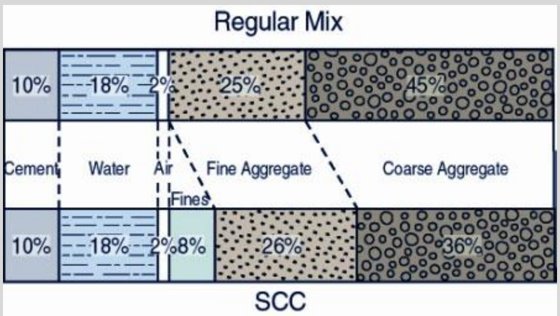


Figure 13: Constituents of self-consolidating concrete (Credit: Self Consolidating Concrete)

The slump test for self consolidating concrete is modified to measure the spread of the collapsed concrete, which may range from 18” to 32 inches, in diameter.

Figure 14: Measuring the spread of self consolidating concrete (Credit: NRMCA)

Professional Practice

Professional Liability Insurance

Professional negligence claims are not unknown in the world. As such, most – if not all – practicing engineers purchase a policy of professional negligence insurance. While the presence of such a policy would financially safeguard the engineer against negligence claims, it would also result in reduction of cases of litigation, which do not benefit anyone.

Insurance companies in Pakistan do not seem to offer such a policy to the engineers, while the soundness of the concept – and potentially the presence of a market – suggests that this service should be made available.

Perhaps the leading insurance companies should be approached by the engineering community for drawing their attention to this area and working out the practical modalities. Perhaps, the PEC or one or more of the professional societies of engineers could play a role in this regard.

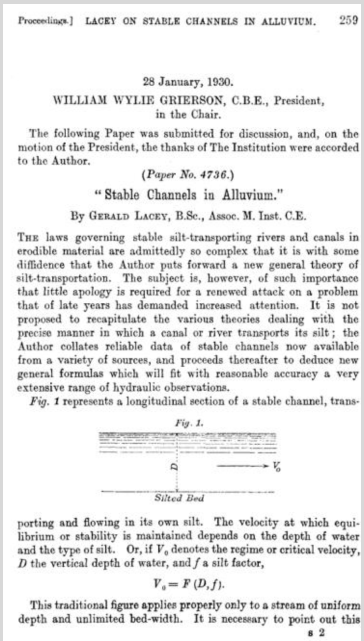
Biography

Gerald Lacey – the Father of Regime Theory

Gerald Lacey was professor of civil engineering (1915-17, 1928-32, 1945) and the last British principal (1945-46) of the research institute in Roorkee, near New Delhi, British India.

He largely owes his fame to the concept of regime theory that was developed by him, for the design of alluvial streams. Lacey was responsible for providing technical guidance and insight that steered successful development of irrigation systems in the Indian sub-continent, during the period of Raj.
In the 1960s, he was involved with the design of large regime canal systems in Iraq with consultants Sir M. MacDonald & Partners, London.

Lacey contributed his seminal paper, under the title of **Stable Channels in Alluvium**, which was first published by the Institution of Civil Engineers, in 1930, in its proceedings.



Proceedings.] LACEY ON STABLE CHANNELS IN ALLUVIUM. 259

28 January, 1930.

WILLIAM WYLIE GRIERSON, C.B.E., President, in the Chair.

The following Paper was submitted for discussion, and, on the motion of the President, the thanks of The Institution were accorded to the Author.

(Paper No. 4736.)

"Stable Channels in Alluvium."

By Gerald Lacey, B.Sc., Assoc. M. Inst. C.E.

The laws governing stable silt-transporting rivers and canals in erodible material are admittedly so complex that it is with some diffidence that the Author puts forward a new general theory of silt-transportation. The subject is, however, of such importance that little apology is required for a renewed attack on a problem that of late years has demanded increased attention. It is not proposed to recapitulate the various theories dealing with the precise manner in which a canal or river transports its silt; the Author collates reliable data of stable channels now available from a variety of sources, and proceeds thereafter to deduce new general formulas which will fit with reasonable accuracy a very extensive range of hydraulic observations.

Fig. 1 represents a longitudinal section of a stable channel, transporting and flowing in its own silt. The velocity at which equilibrium or stability is maintained depends on the depth of water and the type of silt. Or, if V_0 denotes the regime or critical velocity, D the vertical depth of water, and f a silt factor,

$$V_0 = F(D, f).$$

This traditional figure applies properly only to a stream of uniform depth and unlimited bed-width. It is necessary to point out this

s 2

He received Kennedy, Gold Medal, in 1930 and the Telford Gold Medal, in 1958.

Contributing to the Pakistan Civil Engineer

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a) Articles
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d) Your professional and reasoned opinion on an important issue.
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g) Identification of a topic that merits our attention
h) A letter to the editor

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Please make sure that your contributions are free of plagiarism. Where you rely on other sources, please acknowledge and provide complete reference.

Also, please do send us your text contribution in editable format also. The editorial board would have the authority to accept or reject any contribution and also to make editorial changes in the content.