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The Pakistan Civil Engineer

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Cover Story

In the eye of the storm

Storm Picture Credit: Daily Times

The Pakistan
Civil Engineer

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Editorial

This issue focuses on the failure of various transmission line towers in the province of Sind, Pakistan. Information about the matter remains sketchy till now and it may be of interest to the civil engineering community to read what the Pakistan Civil Engineer has been able to collect and analyse.

The Pakistan Civil Engineer continues to seek contributions from those who can contribute in any way.

Looking forward to feedback from the readers,

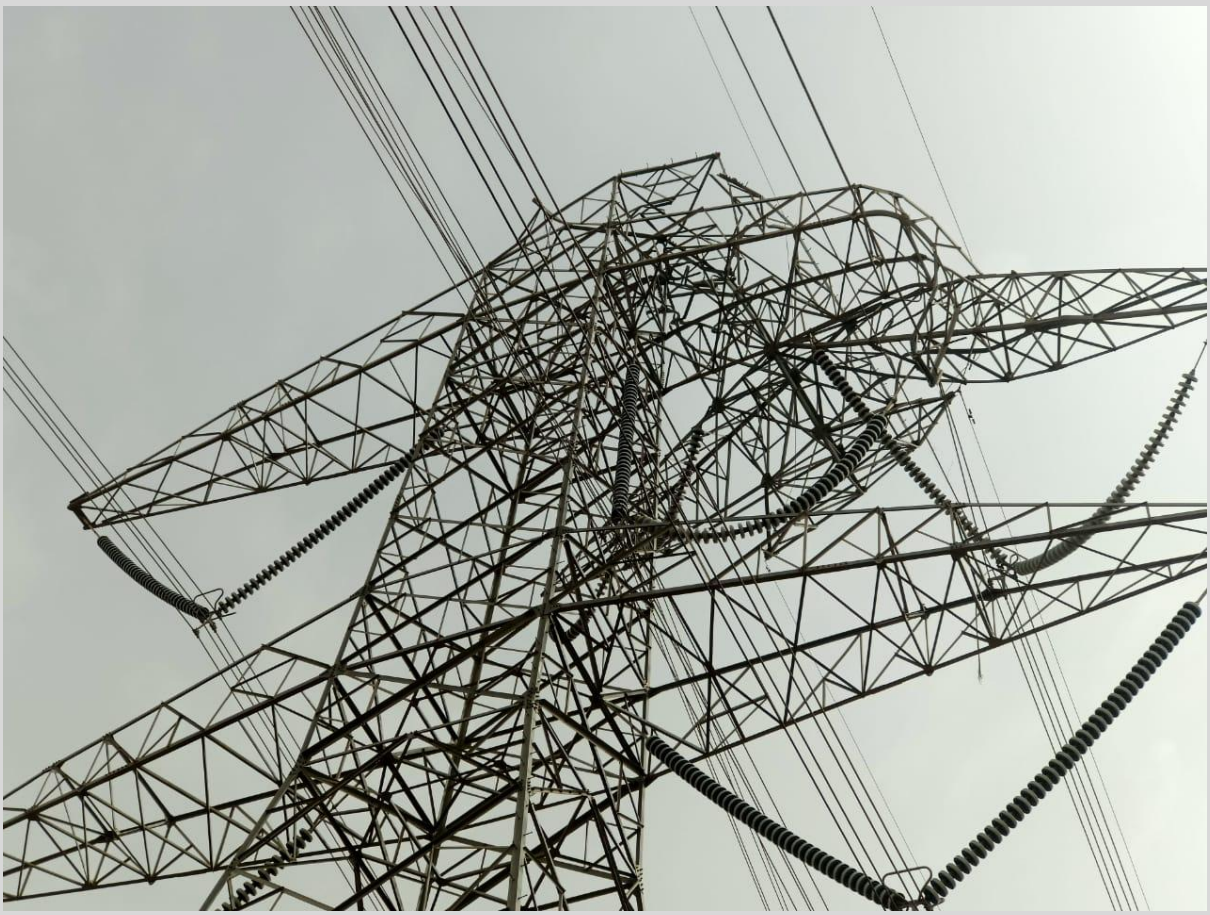
Rizwan Mirza

Rizwan Mirza, CE
Editor-in-chief

Cover Story

In the Eye of the Storm

Tahir Sultan
Editor
with
Rizwan Mirza
Editor-in-chief



ON the fateful day of 27th May, 2021, in a sporadic series of events, one tower after another crumbled to ground in a dramatic cascade effect, as towers of three transmission lines in Pakistan were overtaken by a storm. The rest of the national grid remained uneventful.

The Pakistan Civil Engineer has very little official information at its hand as neither NTDC nor any other governmental organisation has publicly shared the preliminary or final assessment of the underlying causes. Only a perfunctory statement attributing the damage to wind has been shared. It is obvious that for a civil engineer, this raises more questions than it can hope to answer.

What is even more unfortunate is that large natural calamities like the Indian Ocean Cyclone, Tauktae, are also not duly covered by any agency in Pakistan. PSCE feels that civil engineering – in fact no scientific discipline – can progress unless the society adopts an open approach towards all successes and failures. If the experience of the western societies is any guide for us, failures are as much an opportunity to learn as are the successes. Bridges have collapsed, roads have been damaged and many greatly expensive projects gone awry, but the scientific method demanded that a fair and open policy be maintained towards scientific and engineering developments. The dividends are before everyone today and every passing day has enabled man to find out more and more about the laws of nature and has increased its ability to use them to its advantage. Unfortunately, this approach remains alien to Pakistan.

Mystery, therefore, continues to shroud the unfortunate event of the collapse of transmission line towers.

As the magazine of a civil engineering society, The Pakistan Civil Engineer cannot fail to ignore events of the type that have taken place, absence of relevant official technical information notwithstanding. It has to be accepted that structures always have a probability of failure. What is important is how one reacts to a structural failure. The correct sequence of approaching the issue would be to first technically evaluate what happened and identify the lessons learnt.

The moot question, under the circumstances, is the search for the root-cause of the failure. Was it design, material, fabrication, erection, the design criteria or a combination of more than one factor? The Pakistan Civil Engineer would make an attempt to place on record what is known and what is not.

The moot question, under the circumstances, is the search for the root-cause of the failure. Was it design, material, fabrication, erection, the design criteria or a combination of more than one factor?

The Lines Reportedly Affected

According to NTDC:

> NTDC Headquarter WAPDA House Lahore, 24 May 2021: National Transmission and Desptach Company Limited (NTDC) has started rehabilitation work of damaged towers of high power transmission lines caused due to heavy windstorm in southern part of the country. The recent wind storm and torrential rain damaged:
>
> a) 5 towers of 500 kV Transmission Line and Jamshoro - Port Qasim (sic); and
>
> b) 2 towers of 500 kV Jamshoro - Dadu Transmission line
>
> Managing Director Engr. Muhammad Ayub reached to (sic) the site immediately and started supervising the repair work of damaged towers. He directed to complete the rehabilitation work within four days.
>
> It is pertinent to note that alternative source providing full load and no load management is being carried out in any part of country. The recent windstorm played havoc with two extra high voltage transmission lines in Jamshoro which lead to the power suspension of different areas. However, due to availability of adequate power in the system, NTDC managed power supply through alternate sources and the whole transmission system of remained normal and stable in the country.

Figure 1: Managing Director, NTDC, Muhammad Ayub

Damage to towers was reportedly observed, in at least three transmission lines:

a) 500 kV Mateyari-Jamshoro, Double-circuit

b) 500 kV Dadu-Jamshoro, Single-circuit

c) 500 kV Posrt-Qasim-Jamshoro, Double-circuit

The following map of Sind shows its various cities:

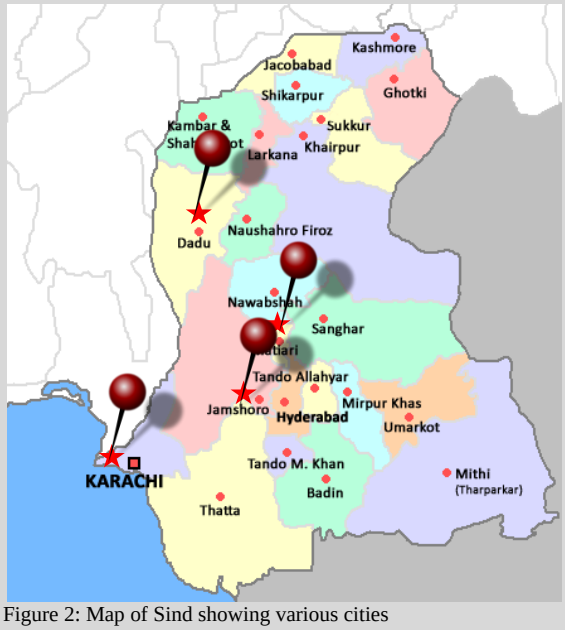


Figure 2: Map of Sind showing various cities

Nature of Damage

500 kV Matiari-Jamshoro Transmission Line

There appears to be a large area of flat land and the area devoid of any wind obstacles. As may be seen, the tower(s) collapsed.

Figure 3: 500 kV Matiari-Jamshoro Transmission Line, Image-01

Figure 4: 500 kV Matiari-Jamshoro Transmission Line, Image-02

Figure 5: 500 kV Matiari-Jamshoro Transmission Line, Image-03

500 kV Dadu-Jamshoro Transmission Line

As may be seen, the tower(s) have collapsed and are badly damaged.

Figure 6: 500 kV Dadu-Jamshoro Transmission Line, Image-01

Figure 7: 500 kV Dadu-Jamshoro Transmission Line, Image-02

500 kV Dadu-Port Qasim Transmission Line

Figure 8: Muhammad Ayub, Managing Director, NTDC, visits damaged tower of Dadu-Port Qasim Transmission Line (Source NTDC)

Various images below show tower failure at different locations:

Figure 9: Scattered pieces of profiles

Figure 10: Scattered pieces of profiles

Figure 11: Tower apex lying at grade

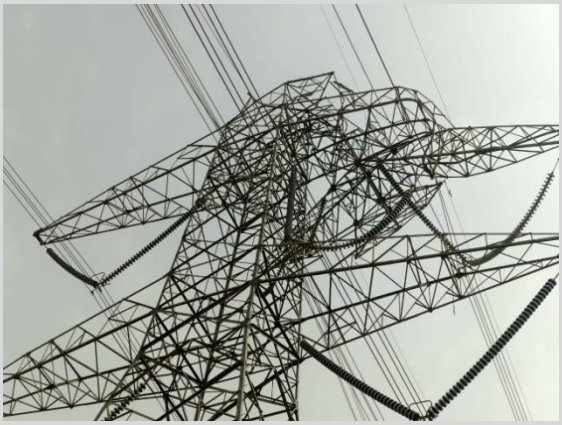


Figure 12: Tower apex

Figure 13: Failed cross-arms

Figure 14: Collapse

Past Experience of Pakistan

With the power stations distributed across the country, Pakistan essentially depends upon a nationwide power transmission grid. Due to large distances involved, the country is not new to long-distance high voltage transmission lines.

The National Transmission and Dispatch Company Limited dispatches electrical power in excess of 23,500 MW.

The existing infrastructure of NTDC includes the following:

Table 1: National Transmission Capacity Source NTDC)

Voltage (kV)	Length (km)	Capacity (MVA)	Sub-stations
500	5,970	22,350	16
220	11,322	31,060	45
Total	*17,292*	*53,410*	*61*

Search for Possible Causative Factors

Without having all the facts at hand, if one were to think of all possible causes of failure, the list would not be small. But by the process of exclusion, some theoretical causes may be ruled out on the basis of known facts.

These are some of the questions that need to be further explored:

In the first place, none of the towers underwent a foundation failure.

In the second place, one can reasonably assume that the towers must have undergone a proper design, an independent design review and a full-scale wind-tunnel testing.

In the third place, the failure was apparently related to wind. What was the velocity of the wind and how turbulent was it, however, remains unknown. Did the wind speed exceed the prescribed design wind speed? Was the adopted design wind speed reasonable?

In the fourth place, conductors have a propensity to experience aerodynamic motions. This includes high-amplitude and low-frequency vibrations, called galloping. This forceful aerodynamic motion may significantly increase forces on the insulators and the towers. The phenomenon is well-known and damping devices and other measures are in vogue for reducing the probability of galloping. Did the conductors experience any aerodynamic effects, such as galloping before the failure?

In the fifth place, damage was reported only in the province of Sind. Was it so because of its relatively close distance from the coast?

In the sixth place, on needs to investigate what is the probability of failure that has inherently been built into the requirements. It is well-established that there always is a probability of failure in each structure and a necessary trade-off has to be made between the capital cost and lowering of the failure probability.

Had everything been done as planned? Did what had happened been considered as a possibility? If not, perhaps the design criteria may need to be required to be revisited. Perhaps, the prescribed design speeds and their dynamic effects may need to be reviewed.

These and many more questions arise as one thinks about the reported events. The answers cannot be found unless all facts are made public.

The Storm

It may be instructive to first provide a perspective on the wind event. Mindful of the impact of effect of wind and earthquakes on civil engineering structures, PSCE continuously to vigilantly follow these events. It, therefore, also followed the storm that loomed large over the Indian Ocean, during the period involved.

Through a Special Issue of its Newsletter, dated 18th May, 2021, Volume 4, Issue 3, PSCE had covered the Indian Ocean tropical cyclone, Tauktae. The tragic event of the transmission line apparently falls within the time window of the same cyclone.

As Tauktae approached land, the U.S. Joint Typhoon Warning Center reported maximum sustained wind speed of 100 knots (185 km/hr or 125 miles per hr) and gusts up to 125 knots (230 km/ hr or 145 miles/hr).


PSCE NEWSLETTER

Tropical Cyclone Tauktae – Special Issue

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PG. 3 Severity
PG. 4 Saffir-Simpson Hurricane Scale
PG. 5 Threat to Pakistan
PG. 6 Join PSCE

A monstrous tropical cyclone, Tauktae, enters the Indian Ocean region.

Rizwan Mirza, CE
Editor-in-chief

A high return-period cyclone, named Tauktae, has entered the Indian Ocean region. While it has already entered India, it is still considered a safe distance away from what was previously considered another potential target – the coast of Pakistan.

Figure 15: An image of the front page of Newsletter of PSCE, Volume 4, issue 3, that reported the cyclone

According to the Saffir-Simpson Hurricane Scale, the event was classified as Category 3 or 4 hurricane.

The Pakistan Meteorological Department, at that time, had not forewarned about expected very heavy damage in Pakistan.

For ready reference, the trajectory of the cyclone is being reproduced below:

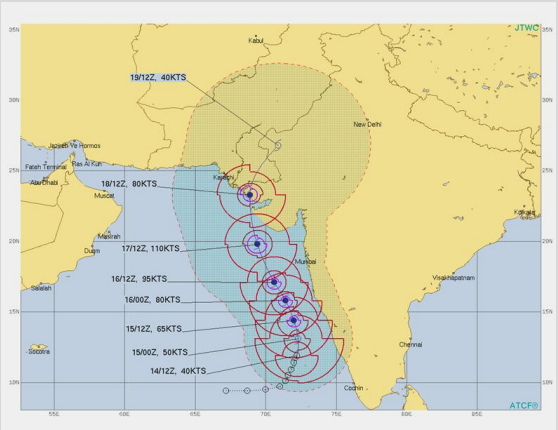
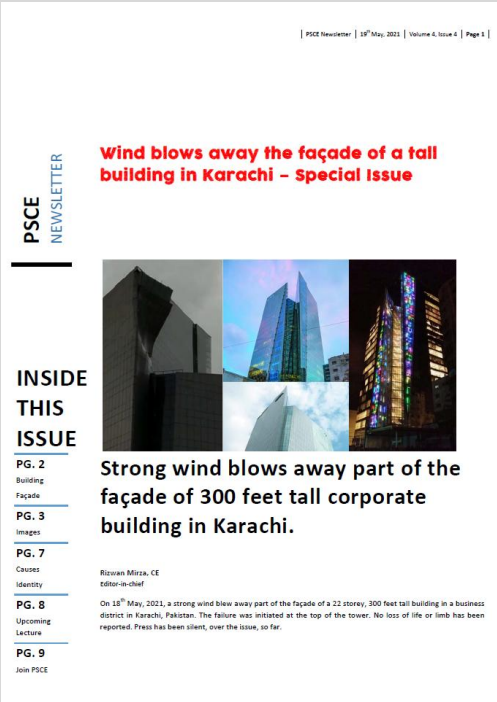


Figure 16: Trajectory of Taukate Cyclone

Pakistan Society of Civil Engineers, again through its Newsletter dated 19th May, 2021, Volume 4, Issue 4, had reported about the event of 18th May, 2021 that blew away the façade of a tall building in Karachi, Pakistan.


PSCE NEWSLETTER

Wind blows away the façade of a tall building in Karachi – Special Issue

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Strong wind blows away part of the façade of 300 feet tall corporate building in Karachi.

Rizwan Mirza, CE
Editor-in-chief

On 18th May, 2021, a strong wind blew away part of the façade of a 22 storey, 300 feet tall building in a business district in Karachi, Pakistan. The failure was initiated at the top of the tower. No loss of life or limb has been reported. Press has been silent, over the issue, so far.

Figure 17: An image of the front page of Newsletter of PSCE, Volume 4, issue 4, which reported the blowing away of the façade of a tall building in Karachi

It is highly probable that the storm of 22nd May, 2021 may well have been an event of the same series.

Epilogue

One can only keep one's fingers crossed, till such time that facts are revealed. As a nation, it would be our best interest to publicly discuss all the facts so that the probability of recurrence of such unfortunate events, in future, may be minimised, or accepted though a techno-economic analysis, if that be inevitable.

The Future

Pakistan lacks something as basic as a nationwide wind speed maps. The 1986 and 2007 versions of Building Code of Pakistan completely failed to address this vital issue.

PSCE, as a representative body of the civil engineering community, would be ready to provide its professional input to The Pakistan Meteorological Department for developing such a map.

As an interim measure, NTDC may contemplate other suitable steps, such as increasing the return period of the design wind speed and an upward revision of the of the category of transmission line structures.

If the actual wind speed during the storm did materially exceed the prescribed wind speed, a valid case may be made out for such a change. In

simple terms, one might consider, for areas prone to strong wind (such as coastal areas), the possibility of increasing the 3-sec gust wind speed to 180 km/hr (about 112 miles/hr), or a fastest mile wind speed of 155 km/hr (about 97 miles/hr). The attendant increase in safety may be weighed against the expected increase in the capital cost.

A New Building Code for Pakistan

Rizwan Mirza
Editor-in-Chief

Pakistan Civil Engineer has learnt that an effort is currently being made to draft a new building code of Pakistan. This would be the third code in a row.

It is well-known that code-making is a complex process and codes are generally developed rather than written. It is also a common practice in the west that the governments, or any of its organisations, are not allowed to play any role in the code-making process. In the USA, for instance, most professional codes are developed by voluntary bodies which are not subject to any control by the government. Even these organisations process in such an orderly manner that no organisation duplicates the work of another.

1986

11 Years

2007

24 Years

2021

THE 1986 CODE

The first code was prepared by a commercial public-sector organisation in 1986. The document was apparently a mixed bag of extracts from various codes used in the world.

Arguably, the 1986 code was a non-starter and ultimately proved out to completely ineffective in ensuring public safety, especially after the devastating 2005 Kashmir earthquake.

THE 2007 CODE

The second was prepared in 2007 and was prepared in the image of the 1997 Uniform Building Code, of International Conference of Building Officials (ICBO), USA, under a mutual agreement.

Rational wind velocity and snow load provisions are missing from this code and no steps had been taken or proposed in order to ensure that these would become available in due course.

Seismic zoning provisions of this code are also at variance with seismic maps of this region prepared by authoritative agencies. The 1997 UBC itself provided seismic zoning of four cities of Pakistan while the Building Code of Pakistan adopted values on the lower side.

The zoning map of the Building Code of Pakistan, 2007 provided the following seismic zoning map for Pakistan:

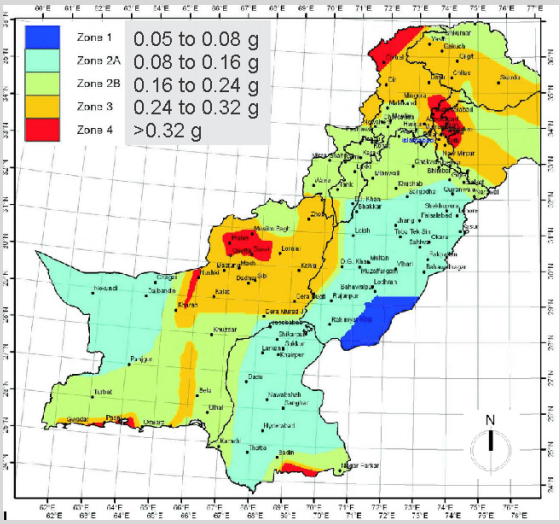

Figure 18: Seismic zoning map provided by Building Code of Pakistan, 2007

It may be noted that the above map is based on a return period of 475 years which represents a 10% probability of being exceeded in 50 years.

For a comparison, the values of peak ground acceleration (pga) documented by the Global Seismic Hazard Assessment program (GSHAP) may be obtained from the following extract from the map:

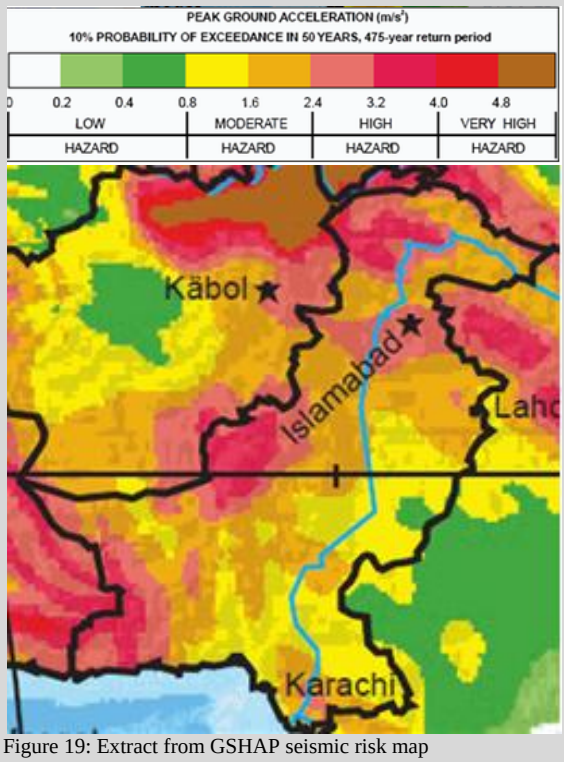

Figure 19: Extract from GSHAP seismic risk map

THE 2021 CODE

Little is specifically known about the current status of the exercise of the revision of the code.

The process of preparing the third code would apparently be lead by the Pakistan Engineering Council (PEC). There is evidence suggesting that this document would be prepared in the light of the 2015 International Building Code (IBC) of the International Code Council (ICC), USA, under a mutual agreement.

Signs are that non-building structures would not be covered by the proposed code. This would be in line with the division of responsibility noted in the United States of America, between various professional bodies.

Unconfirmed reports suggest that PEC intends to have the code enforced forthwith. The author feels that, in principle, such an approach would not be desirable nor is such an approach followed elsewhere in the world, whereby a time-lag is always provided between publishing and enforcement, for a number of practical reasons.

It would be premature to speculate how the specific local details would be handled by the revised document. For seismic parameters, this may, *inter alia*, include Maximum Considered Earthquake MCE_R 5% damped mapped Spectral Response Acceleration at 0.2 Second period, S_s and 1.0 Second period, S_1. The fact is that these and many other similar aspects would constitute the real national annexure to a code that already exists. This is likely to eliminate the need for determining equivalent values based on other available parameters, for those structural engineers who are currently experimenting with the IBC code series in Pakistan.

Epilogue

Regarding the revision cycle, one cannot fail to note that the revision of the 1986 code was made after an elapse of 11 years while the 2007 code is being revised after an elapse of 24 years, which suggests the absence of a self-perpetuating exercise by a professional body. But despite the delay, it is a good omen that a revision is being undertaken at all.

The author feels that the PEC would have been well-advised to ensure an open and informed debate with the objective of identifying the most suitable course to be adopted for a revision. It is in the light of this debate that a process should have been adopted for the exercise of undertaking the revision itself.

The fact is that that, to the extent of generic provisions, any foreign code may be adopted, largely without major difficulties. This is what a country resorts to when it does not have a comprehensive code of its own. But this obviously leads to potential difficulties of implementation.

Biography

Stephen Prokopovych Timoshenko

Степан Прокофьевич Тимошенко

Rizwan Mirza
Editor-in-Chief

23rd December, 1878 – 29th May, 1972

Born in small village named Shpotivka, in Konotop county, Chernihiv gubernia, Ukrainie, Stephen Prokopovych Timoshenko obtained his engineering diploma from Russia.

His father was a serif who later acquired education and himself became a landowner of some standing. His zeal for mathematics and engineering mechanics backed by hard work took him to unprecedented heights of achievement and fame in Europe, US and around the world.

Following are some of the important dates in his life:

Table 2: Important Milestones

1901	Institute of Engineering, Saint Petersburg	Engineering Diploma
1901-1902	Russian army	Military service
1902		Married to Alexandra Archangelskaya – a medical student
1902 - 1903	Mechanics Laboratory, Institute of Engineering, Saint Petersburg Polytechnic	Research assistant
1903 - 1904	Saint Petersburg Polytechnic Institute	Instructor
1904 - 1906	University of Gőttengen, Germany	Student
1906 -1911	Kiev Polytechnic Institute, Kiev, Ukraine	Professor of Strength of Materials and Dean, Division of Structural Enguneering
1913 - 1918	Saint Petersburg Polytechnic and Electrotechnic Institute	Professor
1918 - 1919	Kiev Polytechnic Institute, Kiev, Ukraine	Professor
1920 – 1922	Zagreb Polytechnic Institute	Professor
1922	Vibration Specialty Company	Engineer

1922 – 1927	Westinghouse Research Laboratory, Westinghouse Electric and Manufacturing Company, Pittsburgh, Pennsylvania, USA	Research engineer
1927 – 1936	University of Michigan, Ann Arbour, Michigan, USA	Professor of mechanical engineering
1932	University of Michigan, Ann Arbour, Michigan, USA	Obtain Ph. D. in electrical engineering
1936 – 1944	Stanford University, Stanford California, USA	Professor of mechanical engineering
1944 – 1972	Stanford University, Stanford California, USA	Emeritus Professor of mechanical engineering
1940	National Academy of Sciences	Member
1972		Passed away at Wuppertal, Germany.

As may be noted he lead a very active life with his longest stay of 36 years being at Stanford University. The second long period was 9 years that he spent at the University of Michigan, Ann Arbour. The third long stay of 5 years was at the Westinghouse Research Laboratory. Before 1922 he stayed only for short durations at various positions,

Figure 20: Timoshenko, Kyiv Polytechnic Institute

He was a pioneer at many places that he serves. For instance, he started the Department for Testing Materials (later Department for Technical Mechanics) and also became its first head. During his short-duration teaching activities, he laid the foundations of technical mechanics at the University of Zagreb. He left Zagreb in the summer of 1922, in order to leave for the United States.

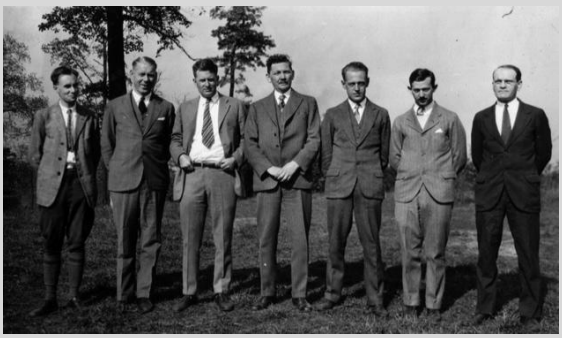

Figure 21: Group photo including JP Den Hartog (extreme left) and SP Timoshenko (middle)

Timoshenko was a prolific write, having to his credit books on the subjects of engineering mechanics, engineering dynamics, strength of materials, theory of elasticity, elastic instability, plates and shells, structural analysis and history of strength of materials, with many serving as text books.

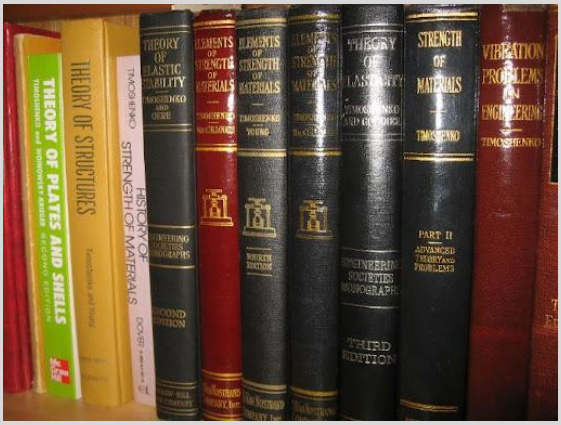

Figure 22: Image of selected works of Timoshenko

He continued to visit Europe except during the period of World War-II. In 1945 the army engaged him to examine what was left of German industry and research laboratories and report on their status to Washington.


Figure 23: Timoshenko Kyiv Polytechnic Institute

In 1958, the trustees of Stanford University named a new facility in his honour: The Timoshenko Laboratory for Engineering Mechanics. In 1958 he visited Russia to be warmly received.

Timoshenko was awarded the memberships of some of the most prestigious scientific bodies:

Table 3: Prestigious memberships awarded

1918	Ukrainian Academy of Sciences, Kiev
1928	Russian Academy of Sciences, Leningrad, Petersburg
1935	Polish Academy of Technical Sciences, Warsaw
1939	French Academy of Sciences, Paris
1940	National Academy of Sciences, Washington D. C.
1944	Royal Society, London
1948	Italian Academy of Sciences, Rome

Honorary doctorate degrees were conferred on him by some of the most prestigious educational institutions:

Table 4: Honorary doctorate conferred

1936	D. Sc.	Lehigh University
1938	D. Engg.	University of Michigan
1947	D. Engg.	Zurich Technical Institute
1949	D. Engg.	Munich Technical Institute
1951	D. Laws	Glasgow University
1954	Sc. D.	University of Boloria
1956	D. Engg.	Zagreb Polytechnic
1960	Sc. D.	Turin Polytechnic

Following is the image of a memorial made in his honour:


Figure 24: A memorial to Stephen P. Timoshenko, in the Kiev Polytechnic Institute campus

Timoshenko also received multiple awards for his work:

Table 5: Awards received

1911	Jourowski Medal and Prize, for Opus on elastic stability	
1945	Salov Prize, for Stresses in railway type tracks	
1935	Worcester Reed Warner Medal	ASME
1939	Lumme Medal	American Society of Engineering Education
1944	Levy Medal	Franklin Institute
1958	Cresson Medal	Franklin Institute
1958	Grand Médaille	Association des Ingénieurs, France
1958	James Watts International Medal	British Institution of Mechanical Engineers
1957	Timoshenko Medal[1]	ASME
1963	James Ewing Medal	British Institution of Civil Engineers

Figure 25: Timoshenko Medal, ASME

The following commemorative postage stamp of Ukraine shows how greatly he is revered in the country of his birth.

[1] Timoshenko was the first recipient of the medal started in his own honour.

Figure 26: A commemorative postage stamp of Ukraine

Stephen Prokopovych Timoshenko remains a legend in the modern history of engineering mechanics.

Contributing to the Pakistan Civil Engineer

The Pakistan Civil Engineer would be happy to receive your contributions. Send a soft copy, whenever possible. You can send:

a) Articles
b) Interesting project pictures (original or free of copyrights)
c) Details of significant civil engineering projects
d) Your professional and reasoned opinion on an important issue.
e) News of professional significance including newspaper clippings, citing source
f) Other important professional information
g) Identification of a topic that merits our attention
h) A letter to the editor

You do not need to be a writer in order to contribute; your professional skill is all we need. Please allow us to make editorial changes before we finally adopt a contribution.

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. The editorial board would have the authority to accept or reject any contribution and also to make editorial changes in the content.

Editor-in-chief's Note

As the Editor-in-chief of the magazine, I feel greatly embarrassed when no contributions are received for most issues, from anywhere.

On one or two occasions when a contribution was received, it was a hard editorial task to ensure that the magazine is not plagued by factual errors and plagiarism. Cut-and-paste policy seems to be the most attractive option for many people, it seems.

With all the emphasis at my disposal, I request everyone to contribute whatever he or she can.

We Need You

PSCE is a young organisation and requires the support of every civil engineer, young or experienced, male or female, working in the industry or in the academia and even the students. We invite everyone to join PSCE and be part of the community.

We have so much to offer: lectures, discussions and publications. Given your increased support, we plan to do much more. We feel that we are second to none – if not the best – in the country, in terms of real professional activity.

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