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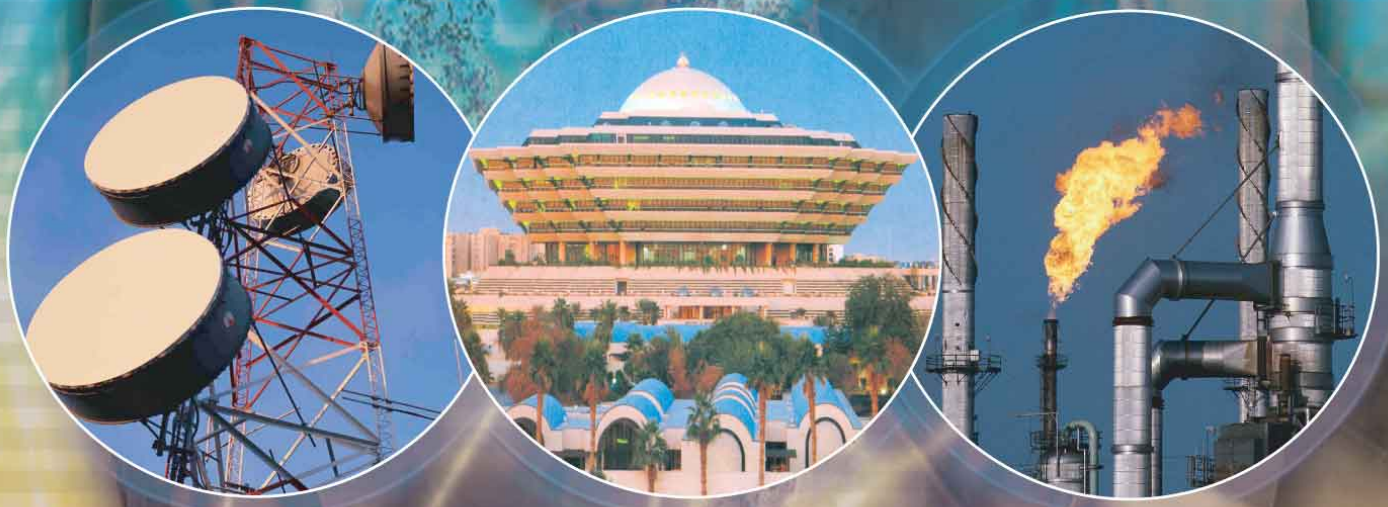

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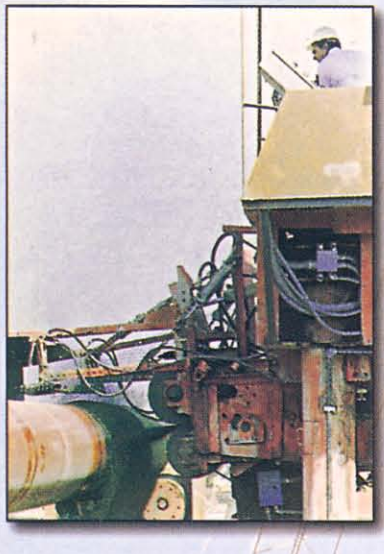

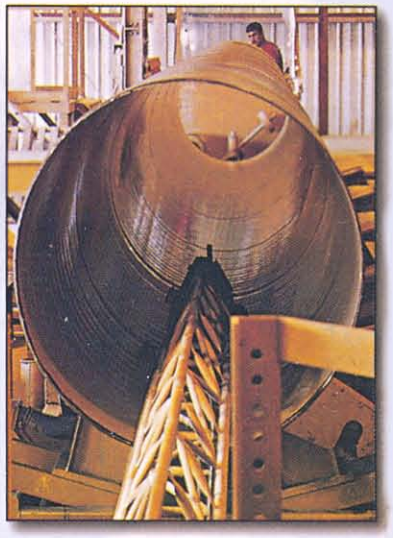

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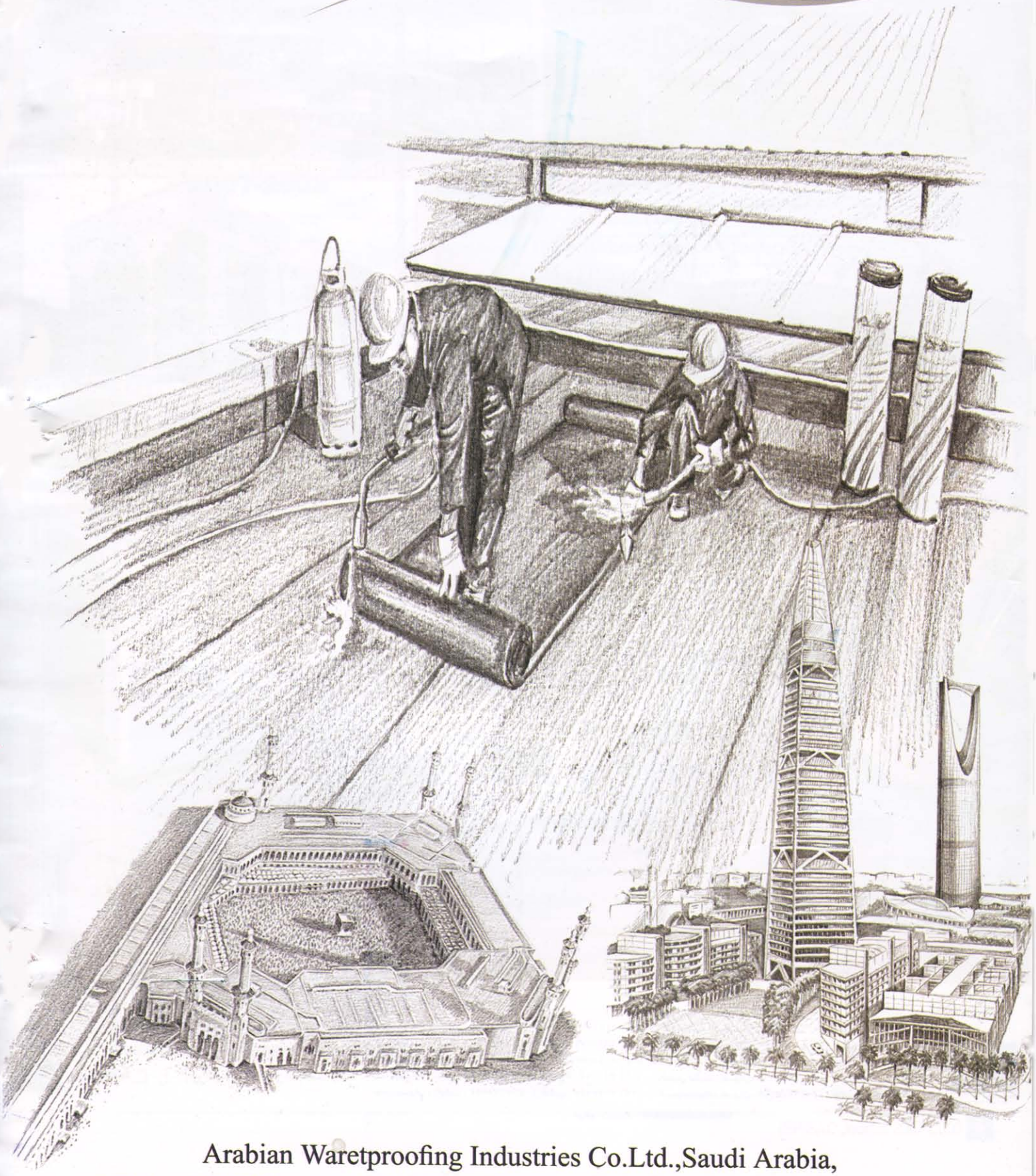

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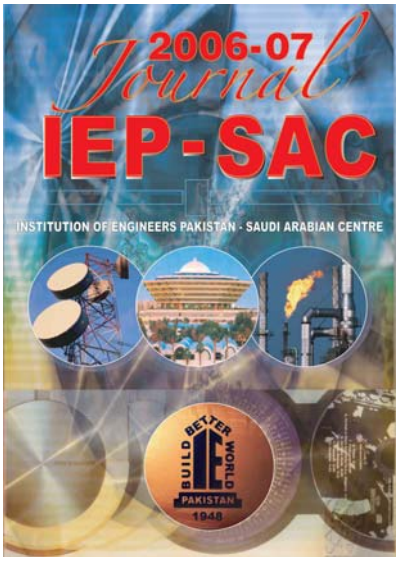

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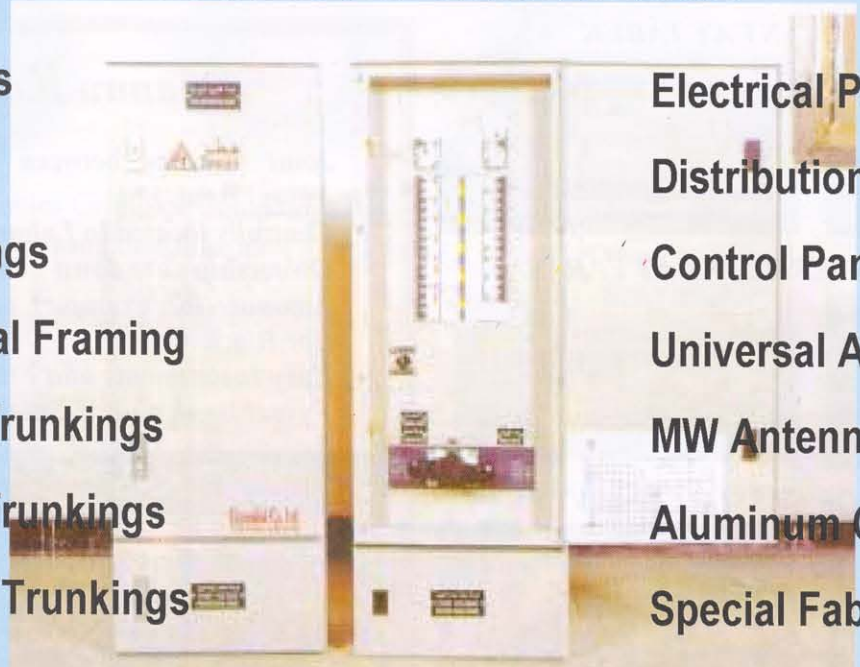

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FOREWORD

The Institution of Engineers Pakistan, Saudi Arabian Centre (IEP-SAC) is pleased to present its current (2006-2007) IEP-SAC Journal. The Journal contains Technical papers of Engineer's interest and an updated directory of Pakistani Engineers in the Kingdom of Saudi Arabia.

Changes are imminent in any organization and the winds of changes have come to IEP-SAC as well. Council had elected me as its new Chairman and Engr. Nazar Malik had been nominated as General Secretary of IEP-SAC. The baton has exchanged hands and I am sure IEP-SAC will move forward to even better and brighter horizons. We all are indebted to our previous chairman Engr. Jaleel Hassan who voluntarily stepped aside to nurture the tradition. Engr. Jaleel Hassan's contribution and efforts in furthering IEP-SAC's causes are unparallel.

IEP-SAC is a live and vibrant albeit a non-profit organization. The main objectives of IEP-SAC are to provide a forum for Pakistani Engineers living in Kingdom to update their professional knowledge, facilitate communication and comradeship and help the new generation of Pakistani Engineers through an ambitious scholarship program. General Secretary's report and the convenor of scholarship committee report in this Journal will highlight IEP-SAC's activities achieving these objectives. You may also visit our website at http://www.iepsac.org.

Even more amazing is the fact that all these events, seminars and activities are organized through absolute voluntarism of IEP Council members whose dedication and commitment to the cause of Pakistani Engineer living in the Kingdom is outstanding.

We wish to express our deep appreciation for the very valuable voluntary services of our IEP Council members in Central and Eastern province. We are also thankful to IEP-HQ Pakistan for their continuous support. We are grateful to the sponsors and advertisers who make the publication of this Journal possible.

We are grateful to H.E. the Ambassador of Pakistan and his Embassy staff for their cooperation and support.

On behalf of IEP-SAC, we wish the express our gratitude to the Kingdom of Saudi Arabia for its hospitality and cooperation to the Pakistani community in the Kingdom in general and Pakistani Engineers in particular.

I very much hope that this Journal will meet your expectations. Suggestions and comments are welcomed.

ENGR. MASOOD KHAN
Chairman
Institution of Engineers Pakistan
Saudi Arabian Centre

11th May 2006
13th Rabi-ul-Thani 1427H

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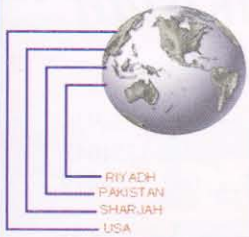

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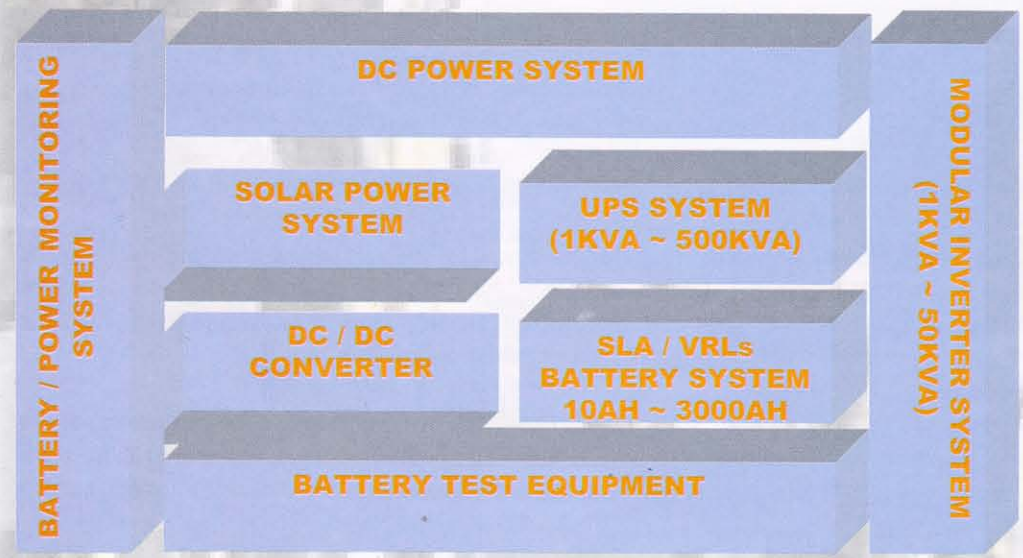

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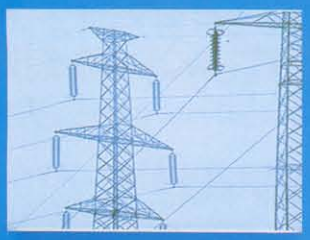

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Message of Admiral Shahid Karimullah (Retd)
Ambassador of the Islamic Republic of Pakistan
to the Kingdom of Saudi Arabia

I wish to congratulate the Institution of Engineers Pakistan - Saudi Arabian Centre (IEP-SAC) for organizing a Seminar on the topic of "Digital Divide and KSA Telecommunication Sector Liberalization Plans". The digital information and telecommunication technologies are advancing at a rapid pace and there is a strong need to provide these services to all the citizens and residents in order to eliminate or reduce any Digital Divide that exist in a society. Therefore, the dissemination of the important information on this topic is very timely and useful

As the Ambassador to the Kingdom of Saudi Arabia, I am pleased to learn that IEP-SAC has distinguished itself as a vibrant forum for Pakistani Engineers, Architects & Town Planners, who have earned good name for their motherland by their sheer hard work, dedication, professional skills and contributions in the development of brotherly Kingdom of Saudi Arabia. By holding seminars from time to time, IEP-SAC provides its members opportunities to share experience and knowledge with each other on a variety of subjects.

I call upon all the distinguished engineering professionals in the Kingdom to keep up their good work with fun devotion and commitment. I wish to assure them of the Embassy of Pakistan's continued support in the pursuit of their professional activities and noble endeavors such as awards of scholarships to deserving and needy students studying in Pakistani Engineering Colleges and Universities.

Finally, may I take this opportunity to congratulate the Institution of Engineers Pakistan - Saudi Arabian Centre for publishing an update of the Directory of Pakistani Engineers Working in Saudi Arabia alongwith several articles dealing with a variety of technical and professional subjects in IEP-SAC Journal, 2006. I am sure that these articles will be of interest to most engineers and IEP-SAC members. I hope that the Directory will not only be a useful source of information for members of IEP-SAC but will also prove equally beneficial to other interested organizations. Finally I am hopeful that the seminar and Directory will help in strengthen the brotherly ties between Pakistani and Saudi Engineers.

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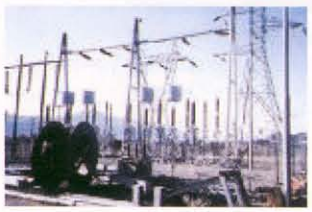

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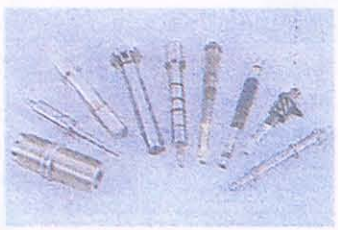

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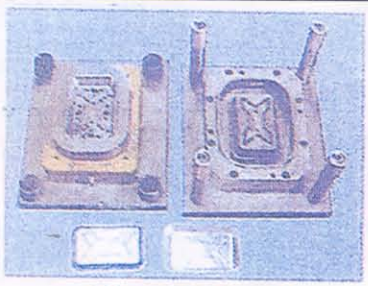

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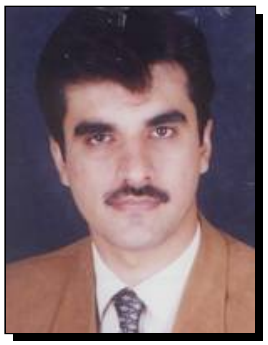

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AL-TUWAIRQI GROUP

Chairman's *Message*

It is with great pride and pleasure to inform you about the tremendous growth and success of Al-Tuwairqi Group. From the establishment of Al-Ittafaq Steel Products Factory (ISPF) in 1989, it was a simple and hand run unit producing merely 1000 tons per month of quality hot rolled steel sections. In a period of 15 years, due to implementation of new and advanced technologies, ISPF has increased its production capacity to 1.250 million tons. This excellent growth, a world record, was achieved through the hard work and dedication of all the team members of Al- Tuwairqi Group.

During this period, we have moved to integrated steel plants. We are committed to our valued clients and customers to provide our best quality products and services, which would bring more profitable benefits for them and to us in the years to come.

I strongly believe that team work, vision, joint efforts, collective ideas, concerted strengths and discipline are the important requisites of our successful business.

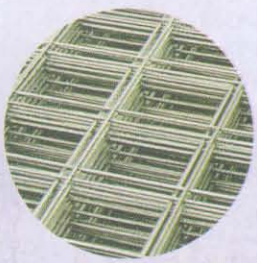
Dr. HILAL H. TUWAIRQI

Company *Profile*

Al -Tuwairqi Group of companies is one of the leading business concerns in the Kingdom of Saudi Arabia. From a humble beginning in 1977, the growth in the last two decades and in the year 1999, made its entry into the top hundred companies in KSA on turnover basis and among the top fifty Saudi companies in terms of the profitability index. With its portfolio of diversified business activities, the Group has gone beyond the boundaries of Saudi Arabia into other areas of Middle East as well. Beside trading and contracting activities, the Group is also engaged in distribution of building and materials, white cement, and trading of industrial materials throughout the kingdom of Saudi Arabia. Al -Tuwairqi Group is extensively engaged in manufacturing various types of products including Steel Billets, Hot Rolled Steel products, reinforced wire mesh, Galvanized Steel , fusion bonded epoxy coated Steel and electrical equipment.

OUR *vision*

Al- Tuwairqi Group is an ISO 9001:2000 and CARES certified company for its production facilities. The Group is a responsible corporate citizen with ethical practices and environment friendly waste disposal methodologies.



It provides a stimulating working environment to attract and retain professionals who are committed to their work and achievements. Dedicated to extend services and reach technical excellence, the Group envisages a vision that continues its core strength and provides the basis for a growing number of satisfied customers.

OUR *Mission*

The management of Al-Tuwairqi Group is enthusiastic for continual improvement of its management quality systems in accordance with the requirement of ISO 9001-2001, CARES and also committed for

- Creating; stimulating and rewarding the work environment.
  Identifying, setting and achieving the quality objectives at relevant functions by providing adequate resources, training and development human resources.
  Providing quality products and services.
  Meeting mutual contractual obligations.
  Ensuring customers satisfaction and enhancing productivity and efficiency.
  Achieving business leadership by devotion.
  Reviewing quality policy periodically.
  Producing quality products according to the international standard.
  Maximum production of iron, steel and electrical products for our clients.
- To provide on timely delivery.
- To maintain efficient customer's services at all times.
- To sustain effective and consideration support to client.

AL-ITTEFAQ STEEL PRODUCTS FACTORY





COMPANY *PROFILE*

Al Ittefaq Steel Products Factory is one of Al- Tuwairqi Group of factories. ISPF is considered as a premier & one of the biggest of its kind in the Kingdom and Middle East in the private sector producing hot rolled, high tensile. Weldable reinforcement steel bars of sizes from 5.5mm to 40mm, manufactured by using the
Thermax Bar Quenching process, conformed to the international standard such as
ISPF is achieving a production of 1.250.000 metric tons per annum.
ISPF has secured its leadership position through its commitment to quality & innovative management thereby forging its policies to meet the future challenges confidently. Since 1998 onward & through an amalgam of targeted Investment; the company has adopted a focused & proactive management, meticulous quality control system from raw material to finished goods, with a world class in-house material testing laboratory.

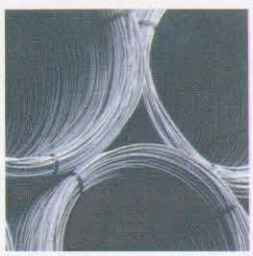
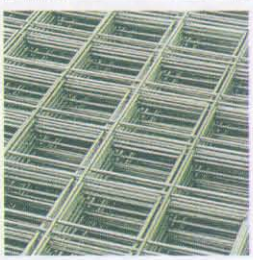
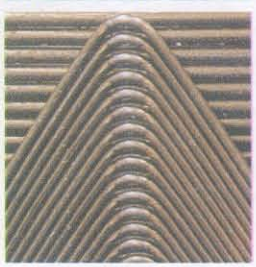
PRODUCTS

ISPF produces high tensile steel bars known as
1- Deformed reinforcement Bars according to ASTM A615Grade 60, Grade 60/40,BS -4449, Grade -460/250,SASO SS A2-1992
Diameter Range: 8,10,12,14,16,18,20,22,25,28.32 and 40mm
Bar Length: 6 Meter and 12 Meters
Bundles: Approx.2,000 Kg-Except 8mm with 1,000 Kg
Annual Production Capacity: 900,000 Tons
2- Wire Rods, generally used to make spring wire, tying wire, nails, wire mesh, galvanized wire etc.
Diameter Range: 5.5mm to 14mm (plain) and 8.0 to 16mm (deformed)
Coil Weight: Approx. 1800 Kg.
Annual Production Capacity: 350,000 Tons

AL-FASAIL STEEL PRODUCTS FACTORY





As Kingdom of Saudi Arabia's economic development emerges strongly, the steel industry has been enhancing & influencing the Kingdom's economic policy& contributing its might in this direction. In this course Al- Tuwairqi Group of companies has emerged as a giant entity. From this entity Al-Faisal Steel Products Factory (FSPF) was born. It is one of the largest downstream steel units in the Middle East under one roof, providing value added steel products

PRODUCTS

Wire Mesh, Galvanized Steel, Cut and Bend Steel Rebar, Spring Wire,Fusion Bonded Epoxy Coated Steel

MAJOR PROJECTS

Due to the big efforts made by our mother company ISPF which is the biggest Hot Rolled high tensile steel mill, we are on the approved list of

Sabic
Saudi Aramco
Sceco
Gasco
Royal commission
Ministry of education

Some of successful projects
King Faisal University
Sceco project
Al Dabal Tower
Al Subaie Tower
Al yammama project

NATIONAL STEEL & IRON FACTORY





COMPANY *PROFILE*

NSIF is a state of the art steel plant producing the steel billets with the option to double the present capacity of 500,000 ton through EAF, LRF & CCM route.

Main facility of the plant includes

Electric Arc Furnace (EAF) of 80 ton capacity.
Ladle Refining Furnace (LRF) of 80 ton.
4 strands continuous Casting Machine.
Scrap storage & management system.
Dust collecting system (DCS) for Environmental & pollution control to collect the dust generated during steel making
Utilities
Substation & SVC system.
Store & ware house.
Central Maintenance shop.

PRODUCTS:

Finished product is billet or bloom. Billets or blooms are sold square or rectangle shape with specific content of iron,carbon,manganese,silicon,chromium,niclel,molybdenum,sulfur,phosphorous etc,as per standard,
Different grades of low carbon steel, medium carbon steel or low alloy steel can be produced.

THAMESTEEL LIMITED





COMPANY *PROFILE*

Thamesteel is based in the southeast of the England in the estuary of the River Thames approximately 80 km form London. Steel making commenced on the current site in 1972.
The Al-Tuwairqi Group purchased the site and production facilities in January 2003 and formed Thamesteel which then commenced production on March 10, 2003.
Thamesteel manufacturers continuous cast billets at the rate of 740,000 tons per annum and the majority of the production is currently shipped to the kingdom of Saudi Arabia for conversion into reinforcing products at AL ITTEFAQ STEEL.

PRODUCTION

The raw material for the steel production is ferrous scrap which is delivered by road and by rail to the site and method I a UHP electric arc furnace with a pre- heating shaft. The steel is reined in one of two secondary steel making units before being continuously cast into high quality 150mm square sections in 6.1 and 9.5 lengths. Before transferring to the docks for shipment the billets are packed into 10 tons units for ease of handling. The packs are assembled into 50,000 tons lots for loading on to vessels in sheerness docks, located just 0.5 km from the works. A direct transfer to Dammam takes approximately 21 days.
In preparation for the build up of tonnage at NSIF which will supply rolling in Dammam, Thamesteel has started to develop more local outlets for the sale of its billets though development is at an early stage. During 2005 a bar rolling mill will be installed on the Thamesteel site and the production from this unit will gradually build to approximately 500.000 tons per annum by which time the Saudi factories will be more self sufficient to feed stock for their mills.

THE INTERNATIONAL ELECTRICAL PRODUCTS COMPANY

Electrical Division of Al Tuwairqi Group is one of the pioneers in the switchgear industry in the kingdom of Saudi Arabia.

It started its manufacturing activities in 1987 for the Medium and low voltage switchgears. In 1998 the premises was upgraded to build a new and modern factory with the name 'The International Electrical Products Est (TIEPCO).

Within short span of time since inception of its modern plant TIEPCO is now enjoying status of approved manufacturer for Saudi Electricity Company for numerous products like Metered CB Ring Main units, package substations and Relay control Panels. For Saudi Aramco TIEPCO is the approved manufacturer of relay and control panels. For government ministries and departments and for the industrial and building sector TIEPCO is also supplying value added metal Clad switchgear under partnership agreement with world renowned manufacturer Alstom (Areva)

TIEPCO has recently launched its Automation wing in order to further explore business in the manufacturing if automation panels and intelligent motor control centers. Further more TIEPCO is providing systems integration services through this wing.

Other Divisions of Al-Tuwairqi Group

The Scientific and Medical Division (SMD) is comparatively a younger member of Al-Tuwairqi group. Born in 1998, SMD ,thru direct marketing channel is serving Health Care and medical research units by offering quality products and after sales services for
Leica microsystem,compound+Stereo+Surgical+Scanning Microscope, LEO Electron Microscope,Forensic Science Equipment,medical kits. Etc

Industrial Supply Division (ISD),thru its extensive network of dealers is serving the local industries by offering top quality industrial consumables like working and welding gloves, Neoplene rubber sheets welding rods, V-belts, safety shoes tie wires ,Solid MIG and flux core wires etc.

IT Division is providing seamless integration of the Group by customized MIS and implementation of SAP. Finance and cost ,material management. sales and distribution, quality management modules have already successfully been implemented.

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Al-Fasail Steel Product Factory
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GLIMPSES OF IEP-SAC ACTIVITIES

(Left) Engr. Abdul Qadus Minhas is reciting verses from Quran at the occasion of a seminar on *"Science and Technology Parks"* held on 16th December 2004.

(Center) Engr. Abdur Rashid Shad, Convener Awards & Scholarship Committee, is presenting his report.

(Right) Engr. Dr. Nazar Malik, Convener Seminar Committee, is introducing the speaker.

A photo of the speaker with IEP-SAC executives during the procession of Seminar on *"Science and Technology Parks"* held on 16th December 2004.

Sitting form left to right are Engr. Masood A. Khan (General Secretary IEP-SAC), Dr. Nazar Malik (Convener Seminar Committee), Engr. Jaleel Hasan (Chairman IEP-SAC) and the Speaker, Dr. Sadik Seith.

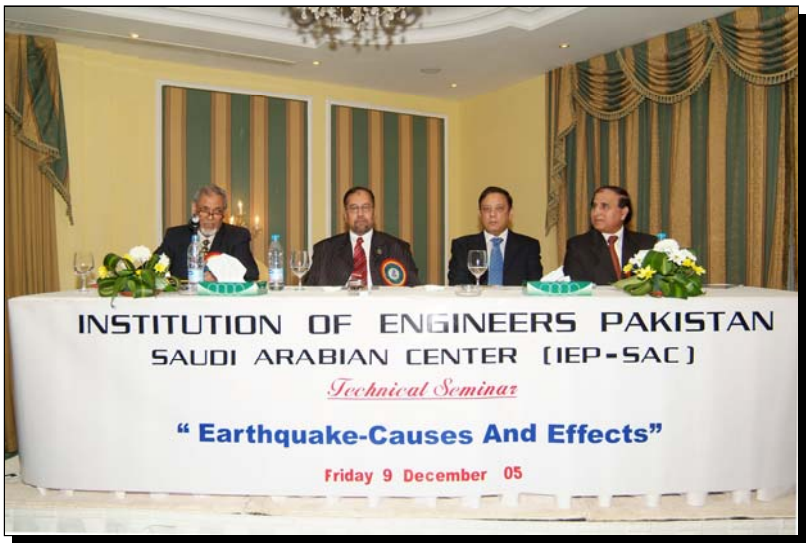
Engr. Jaleel Hasan, Chairman IEP-SAC, is presenting a memento to the keynote speaker, Dr. Sadik Seth, on the occasion of a seminar on *"Science and Technology Parks"*.

GLIMPSES OF IEP-SAC ACTIVITIES

(Left) The Chief Guest is addressing the audience at the occasion of a technical seminar on *"Earthquake - Causes & Effects"*, held on 9th December 2005 at Minhal Holiday Inn, Riyadh.

(Center) Engr. Jaleel Hasan, Chairman IEP-SAC presenting his address.

(Right) Engr. Masood A. Khan, General Secretary IEP-SAC, is delivering his message.



A photo of the chief guest with IEP-SAC executive during the procession of a technical seminar on *"Earthquake - Causes & Effects"*, held on 9th December 2005.

Sitting from left to right are Engr. Mubashir H. Kirmani (Speaker), Engr. Jaleel Hasan (Chairman IEP-SAC), the Chief Guest and Engr. Masood A. Khan (General Secretary IEP-SAC)

A impressive view of audience of a seminar on *"Earthquake - Causes and Effects"* held on 9th December 2005 at Minhal Holiday Inn, Riyadh.

GLIMPSES OF IEP-SAC ACTIVITIES

A group photo of IEP-SAC Local Council members with the Speaker and the Chief Guest on the occasion of a seminar on *"Science and Technology Parks"* held on 16th December 2004.

Prominent in the picture are Engr. Syed Zafar Ahmed, Engr Mubashir Kirmani, Engr. Abdur Rashid Shad, Engr. Masood Khan, Dr. Nazar Malik, Dr. Sadik Seth (Speaker) and Engr. Saifullah Saleem.

A group photo of some of the IEP-SAC Local Council members with Chief Guest on the occasion of a seminar on *"Earthquake - Causes and Effects"* held on 9th December 2005 at Minhal Holiday Inn, Riyadh.

Standing from left to right are Engr. Jawed Iqbal, Engr. Syed Zafar Ahmed, Engr. Jaleel Hasan, the Chief Guest, Engr. Masood Khan, Engr. Obaidullah Siddiqi and Engr. Sheikh Ahkhtar Hussain.

The participants are enjoying Lunch at the occasion of *"Annual Picnic and Family Get-together"* held on 24th March 2005.

GLIMPSES OF IEP-SAC ACTIVITIES

The Social Activities Committee is distributing prizes to the winners of the games at the occasion of *"Annual Picnic and Family Get-together"* held on 24th March 2005.

Prominent in the picture are Engr. Waheed Mir, Engr. Obaidullah Siddiqu, Engr. Jaleel Hasan, Engr. Shaikh Asrar Ahmed and Engr. Saifullah Saleem.

The participants of the *"Annual Picnic and Family Get-together"* are watching the Prize Distribution Ceremony.

Some of the participants of the *"Annual Picnic and Family Get-together"* are watching Cricket.

GLIMPSES OF IEP-SAC ACTIVITIES

The young kids are participating in a Straw Collection competition at the occasion of *"Annual Picnic and Family Get-together"* held on 17th February 2006.

The kids are competing in a Carrom Board competition.

The Social Activities Committee is distributing prizes to the winners of the games at the occasion of *"Annual Picnic and Family Get-together"* held on 17th February 2006.

Prominent in the picture are Engr. Masood Khan, Engr. Shaikh Asrar Ahmed, Engr. Obaidullah Siddiqu, Engr. Saifullah Saleem and Engr. Waheed Mir.

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GENERAL SECRETARY'S ANNUAL REPORT

I have the pleasure to present the annual report of IEP-SAC on the activities and events that took place during the year 2004-2005. I have taken over the helms of General Secretary ship from Engr. Masood Khan who had been elected Chairman of IEP-SAC from this year.

IEP-SAC has been actively pursing its objective of creating a community spirit and fellowship among Pakistani Engineers working in the Kingdom of Saudi Arabia. In addition, IEP-SAC strives for disseminating and sharing of latest technical knowledge among engineers. IEP-SAC also runs an ambitious scholarship program.

IEP-SAC has continued to pursue its above stated objectives in this reporting period with full enthusiasm. A brief of the activities since November 2004 is given below:

IEP-SAC organized its annual seminar and dinner on 16 December 2004. Prof. Dr. Sadik Seth of KFUPM was the keynote speaker. The topic of the seminar was *"Science and Technology Parks"*. On this occasion IEP-SAC also published its annual journal including the directory of Pakistani engineers residing in the Kingdom of Saudi Arabia.

The great annual social event of IEP-SAC is the family picnic. Two family picnics were organized during the reporting period; one on 25 March 2005 and the other on 17 February, 2006. Family picnics are very successful events attended by over 150 families each time in a rest house at the outskirts of Riyadh. Family picnics provide opportunities for cementing ties among engineering community in a relaxing and entertaining environment.

A Technical Seminar was organized and conducted on 09 December, 2005. The topic of this seminar was *"Earthquake: Causes & Effects"*. The presentation was given by Engr. Mubashir H. Kirmani of Rashid Engineering. The seminar proved to be very interesting and was well received by engineering community in Riyadh.

IEP-SAC has increased its scholarships awards to 85 students this year to provide financial assistance to the needy and deserving students in Pakistan. The recipients are selected from 11 public sector Engineering Universities / Colleges spread all over Pakistan and Azad Kashmir.

I appreciate the dedication of our Council members in making all of the above events a great success. I also appreciate the support and guidance of IEP head quarter and the full support we enjoy from the Pakistan Embassy in Riyadh. I am grateful for the support of all Pakistani engineers living in the Kingdom and finally my personal appreciation of our Chairman IEP-SAC Engr. Masood Khan and his predecessor, Engr. Jaleel Hasan for their wholehearted support and guidance in running the affairs of IEP-SAC. Finally I wish to convey my deep appreciation to all brother engineers, sponsors, advertiser, guests, press and media personnel and well wishers for their cooperation and support of IEP-SAC activities.

ENGR. DR. NAZAR H. MALIK
General Secretary
Institution pf Engineers Pakistan
Saudi Arabian Centre

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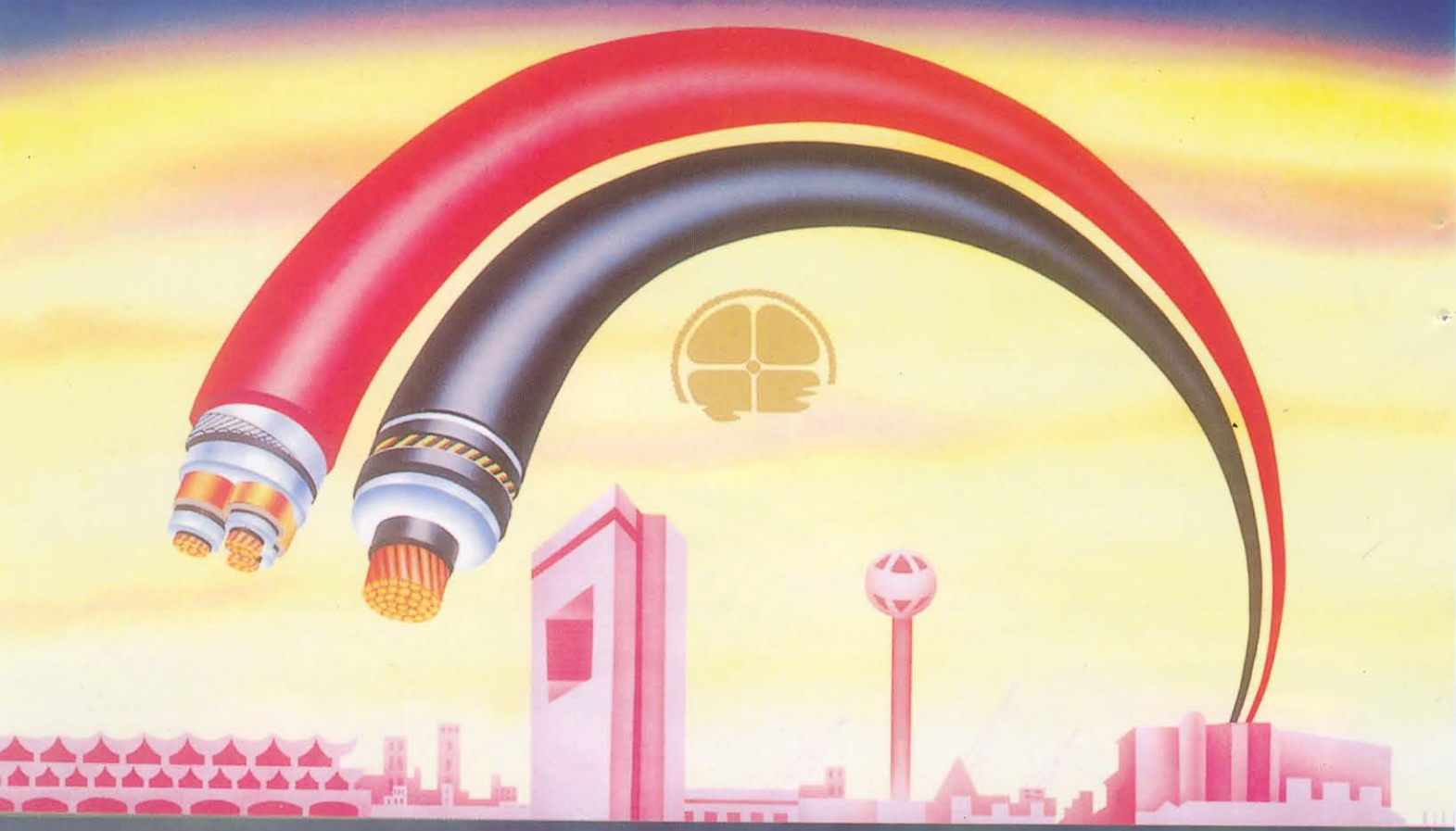

مواجهة التحديات ومواكبة التغيرات

منتجاتنا على الدوام متوافقة للأداء في أصعب الظروف

منتجات الشركة:

١- كابلات الضغط المتوسط والعالي.

* كابلات ثلاثية الأوجه معزولة ومسلحة وغير مسلحة حتى جهد ٢٢٠ ك.ف.
* كابلات أحادية الوجه - معزول المادة XLPE حتى جهد ٢٢٠ ك.ف.

٢- كابلات الضغط المنخفض:

* كابلات متعددة الأوجه ومفلطحة ذات موصلات نحاسية مصمتة أو مجدولة معزولة ومغلفة بمادة الـ P.V.C
* كابلات أحادية الوجه ذات موصل مصمت أو مجدول من النحاس ومعزولة بمادة الـ P.V.C
* كابلات أحادية الوجه ذات موصلات مرنة ومعزولة بمادة الـ P.V.C
* كابلات متعددة الأوجه ذات موصلات نحاسية مرنة معزولة ومغلفة بمادة الـ P.V.C
* كابلات متعددة الأوجه ومفلطحة ذات موصلات نحاسية مصمتة مجدولة معزولة مغلفة بمادة الـ P.V.C
* كابلات ضغط منخفض للتمديدات الداخلية.

٣- كابلات ضد الحريق وقليلة الأدخنة غير محتوية على الهالوجين وذلك للإستخدامات الخاصة.

٤- كابلات دعامية هوائية.

٥- موصلات هوائية.

* موصلات نحاسية قاسية ومعزولة بمادة الـ P.V.C

٦- كابلات للتمديدات الداخلية.

٧- كابلات التحكم.

٨- كابلات اخرى متخصصة.

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AWARDS AND SCHOLARSHIP COMMITTEE
CONVENER'S REPORT

AL-QURAN

*To spend your substance, out of love for Him, for your kin, for orphans, for the **needy**, for the wayfarer, for those who ask and for the ransom of slaves; (2:177)*

*If ye disclose (acts of) charity, even so it is well, but if ye conceal them, and make them reach, those (really) in **needs**, that is best for you. It will remove from you some of your (stains of) evil. And Allah is well acquainted with what ye do. (2:271)*

By the grace of Allah the Almighty, the scholarship Program for needy and academically sound students in Pakistani Engineering Universities and Colleges was launched in the year 1996. Eleven Universities and Colleges – as listed below are taking benefit from this program.

1. University of Engineering and Technology, Lahore
2. University of Engineering and Technology, Taxila
3. University College of Engineering and Technology (Bahauddin Zakariya University), Multan
4. Institute of Chemical Engineering and Technology (University of Punjab), Lahore
5. Dawood College of Engineering and Technology, Karachi – Affiliated with Mehran UET Jamshoro
6. NED University of Engineering and Technology, Karachi
7. Mehran University of Engineering and Technology, Jamshoro
8. Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah
9. NWFP University of Engineering and Technology, Peshawar
10. Balochistan University of Engineering and Technology, Khuzdar
11. University College of Engineering and Technology, Mirpur (AJ&K)

This program serves all the four provinces of the Islamic Republic of Pakistan and The State of Azad Jammu and Kashmir. The Rules and Regulations, Selection Criteria and Forms can be read and printed out from IEP-SAC website (http://www.iepsac.org). Ten (10) batches for 152 needy students had been launched so far. By the help and blessing of Allah the Almighty, 60 students are serving our homeland after graduation by benefiting this program.

We had started the scholarship program 10 years ago and we had maintained its continuity. I take this opportunity and appeal to engineers in particular and Pakistani community in general to please join hands in this noble and just cause. It is a service to Pakistan. Let us make more effort to continue and expand the program. Your suggestions to improve the program further will be most welcomed. For more information please contact any of the members of Awards and Scholarship Committee or any Local Council Member.

ENGR. ABDUR RASHID SHAD
Convener Awards and Scholarship Committee
Institution of Engineers Pakistan
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EARTHQUAKE: CAUSES, EFFECTS AND SAFETY PRECAUTIONS

BY ENGR. S.M.H. KIRMANI
Rashid Engineering (Consultant)
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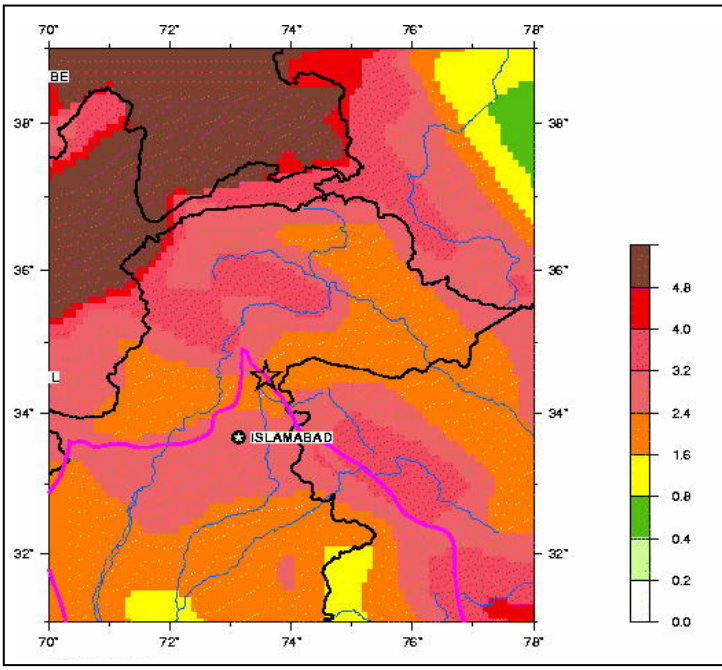
ABSTRACT

This paper describes the causes of the earthquakes, its effects and safety precautions in design of the structure in various seismic zones in compliance with the Building codes. This study has also focused on the development and enforcement of a crisis management in order to mitigate the effects of an earthquake.

INTRODUCTION

Trembling or shaking movement of the earth's surface is known as Earthquake. Most earthquakes are minor tremors. These are due to slow movement of fault in the form of creep. Larger earthquakes usually begin with slight tremors but rapidly take the form of one or more violent shocks, and end in vibrations of gradually diminishing force called aftershocks. The subterranean point of origin of an earthquake is called its focus; the point on the surface directly above the focus is the epicentre. The magnitude and intensity of an earthquake is determined by the use of scales, e.g., the Richter scale and the Mercalli scale respectively.

Pakistan was struck, on Saturday October 08, 2005, by the worst ever earthquake in its history with a magnitude of 7.6 on Richter scale. The earthquake affected the Northern area of Pakistan and Azad Kashmir causing human damages at an unprecedented level. The epicentre of this earthquake was about 10 kilometres Northeast of Muzaffaraba at the Head of Neelum Valley. Latitude and longitude of the epicentre was 34.539 and 73.588



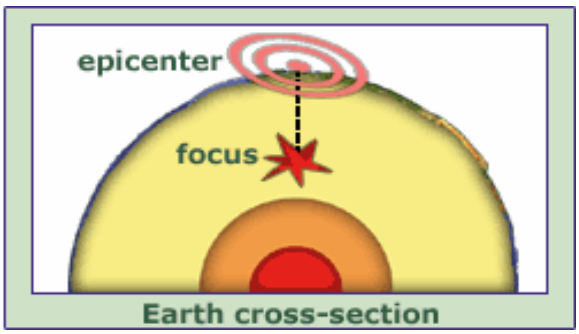


Figure 1: Earthquake in Pakistan
2005 10 08 03:50:40 UTC 34.52N 73.58E
Depth: 26 km, Magnitude: 7.6
Peak Ground Acceleration (m/s^2) with 10%
Probability of Exceedance in 50 Years
Major Tectonic Boundaries: Subduction Zones -purple, Ridges -red and Transform Faults -green
USGS National Earthquake Information Center

respectively. Focus was just 26 km under the surface of the earth. According to the seismologists and scientists, the main cause of the recent earthquake in Pakistan and Azad Kashmir was the collision of the Indian tectonic plate, which is moving towards the North, with Eurasian plate and resulted in a destructive earthquake.

GEOLOGY OF EARTH

The earth has a zoned interior, consisting of concentric shells differing from one another by size, chemical composition, and density. The earth is much denser near the centre than it is at the surface. The average density of rocks near the surface is 2.8 g/c.c. while the average density of the entire earth is 5.5 g/c.c.

The following are the various shells:

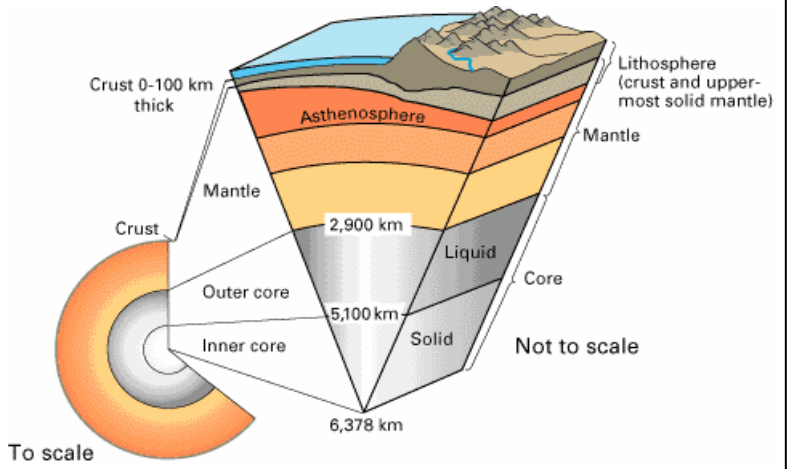


Figure 2: Geology of Earth

Earth's Crust

The outer shell is called crust which varies from 8.0 to 100.0 km in thickness, and consists of the continents and ocean basins at the surface. Crust is composed of less denser materials like, Ca, Na, Aluminium-Silicate. Being relatively cold, the crust is rocky and brittle, so it can fracture in earthquakes. Total area of the crust surface is 510.2 million sq. km, oceans are 361.3 m sq. km. and dry land is 148.9 m. sq. km.

Moho

The Austro-Hungarian meteorologist "ANDRIJA MOHOROVICIC" discovered a boundary between the crust and mantle, now called the Mohorovicic discontinuity or Moho. Moho is considered to be the mantle's upper surface. The boundary is between 25 and 60 km deep beneath the continent and between 5 and 8 km beneath the ocean floor.

Mantle

The portion of the Earth's interior lying beneath the crust and above the core, extending to a depth 2,900 km. is called Mantle. The mantle consists of very dense (average density of 3.9 g/c.c.) rock rich in iron and magnesium minerals. At over 1000 ^{o}C, the mantle is solid but can deform slowly in a plastic manner.

Lithosphere

Lithosphere consists of the heavy oceanic and lighter continental crust, along with the part of the solid upper mantle. The thickness of the lithosphere varies from 1.6 km to 130 km. beneath the ocean crust, whereas the thickness of the continental lithospheric plate is about 300 km.

Asthenosphere

The lithosphere rests on a semi molten plastic layer called the asthenosphere, over which the plates of lithosphere glide. The rocks in this region are very close to melting, and the zone represents a fundamental boundary between the moving crustal plates of the earth's surface and the interior regions. It is considered that the heat energy released in the upper part of the mantle has broken the earth's crust into vast plates that slide around on the plastic zone, setting up stresses along the plate margins that result in the formation of fold and faults.

Core

Core of the earth lies below the mantle: the outer 2200 km. of the core is molten. It is concluded that the inner 1260 km of the core is solid. The outer core is thought to be the source of the earth's magnetic field. According to the theory of W.M. Elasser and F. Bullard, the tidal energy or heat energy is converted to mechanical energy in the form of currents in the liquid core. This mechanical energy is then converted to electromagnetic energy, which we see at the magnetic field. Magnetic polarity reversal of Earth has occurred at irregular intervals during geologic time. Polarity reversal can be preserved in sequences of magnetized rocks and compared with standard polarity change-time scale to geological ages of the rock. Rocks created along the oceanic spreading ridges commonly preserve this pattern of polarity reversals as they cool, and this pattern can be used to determine the rate of ocean ridge spreading.

CAUSES OF EARTHQUAKES

General

The concept regarding the causes of earthquakes varied through history, from fantastic to supernatural, to mysterious, to religious and finally to natural. Aristotle contended that all earthquakes were caused by air or gases trying to escape from subterranean cavities. However, in the late 19th century as a result of extensive investigations, seismologist concluded that most of the earthquakes are related to compressional or tensional stresses built up at the margins of the huge moving lithospheric plates that make up the earth's surface. The immediate cause of most earthquakes is the sudden release of stress along a fault, or fracture in the earth's crust, resulting in movements of the opposing blocks of rock past one another. These movements cause vibrations to pass through and around the earth in wave form, just as ripples are generated when a pebble is dropped into water. Volcanic eruptions, rock falls, landslides, and explosions can also cause a quake, but most of these are of only local extent.

Fault

a) In geology, fracture in the earth's crust in which the rock on one side of the fracture has measurable movement in relation to the rock on the other side is called as "Fault". Evidence of faults are found either at the surface (fault surface) or underground (fault plane). Faults are most evident in outcrops of sedimentary formation where they conspicuously offset previously continuous strata.

Movement along a fault plane may be vertical, horizontal, or oblique in direction, or it may consist of rotation of one or both of the fault blocks. Movements are associated with mountain building and plate tectonics. San Andreas Rift in California extends to 600 miles. Depth 16 km (10 miles) and width from a few hundred feet to a mile wide. During the disastrous San Francisco earthquake of 1906, the rapture and displacement of the earth crust along this fault took place upto 190 miles, and horizontal displacement was upto 22 ft. (6.7 m) where as the total accumulative displacement was 350 miles since 15 to 20 millions years. As a result of earthquake in California on March 26, 1872 vertical displacement upto 25 feet (7.6 m) took place.

Figure 3: San Andreas Rift in California

b) **Classification of faults:** These are summarized as following:

- Dip slip (up and down movement).
  - Normal fault
  - Thrust (Reverse) fault
- Strike slips (Movement parallel to the fault plane). (The San Andreas fault of California is of this type).

Faults which move along the direction of the dip-plane are dip-slip faults, normal or reverse depending on their motion. In dip-slip fault the term "hanging wall" is used for the side that lies vertically above the other, called the "footwall". A fault in which the hanging wall moves down and the footwall is stationary is called a normal fault. Normal faults are formed by tensional, or pull-apart, forces. A fault in which the hanging wall is the up thrown side is called a thrust fault because the hanging wall appears to have been pushed up over the footwall. Such faults are formed by compressional forces that push rock together and are by far the most common of the dip-slip faults.

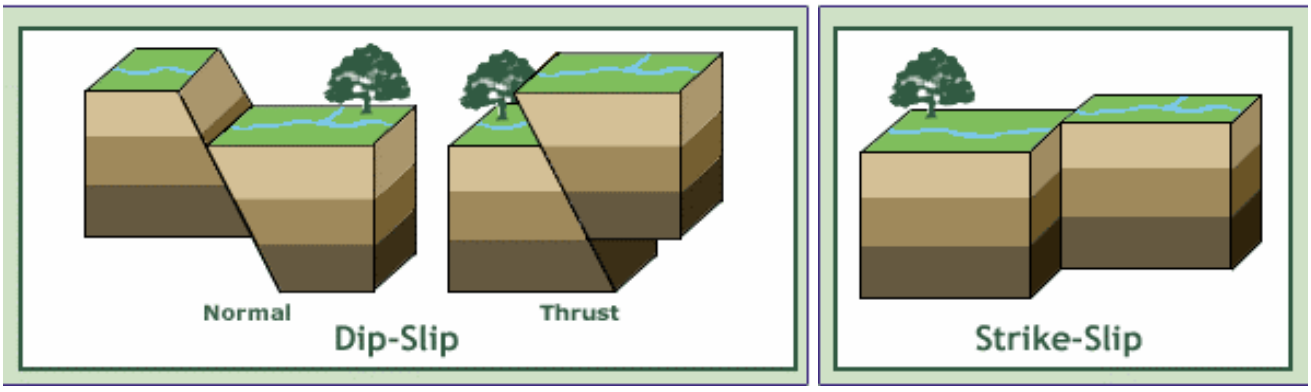


Figure 4: Classification of Faults

Faults which move horizontally are known as strike-slip fault and are classified as either right-lateral or left-lateral. Faults which show both dip-slip and strike-slip motion are known as oblique-slip fault.

All types of faults have been recognized on the ocean floor. Normal faults occur in the rift valleys associated with mid ocean ridges spreading at slow rates; Strike-slip faults appear between the offset of mid-ocean ridges; and thrust faults occur at subducting plate boundaries.

Active faults, though they may not move for decades, can move many meters in a matter of seconds, producing an earthquake. The largest earthquakes occur along the thrust faults.

- Some faults creep from a half inch to as must as 4 inch (1 to 10 cm.) per year.
- Fault movements are measured using laser and other devices.

Plate Tectonics

Plate tectonics is the continual slow movement of the tectonic plates. It is the theory that unifies many of the features and characteristics of "continental drift and sea floor spreading".

Plate tectonics theory holds that "lithosphere", the hard outer layer of the earth, is divided into about 7 major plates and perhaps as many as 12 smaller plates, 130 km thick, resting upon a lower soft layer called the asthenosphere. The continents, which are 8.0 to 100 km thick, are embedded in some of the plates, and hence move as the plate move about on the earth's surface. The majority of earthquakes result from the structural changes in the crust of the earth. They are called tectonic earthquakes.

The mechanism of moving the plates is probably related to the transfer of heat energy or convection within the earth's mantle. As heat continues to emanate from the earth into outer space, the volume of the earth constantly reduces. As this shrinkage of the volume proceeds toward the centre of the globe, the rigid crust of the earth accommodates itself by folding and crumpling.

Plate Boundary Condition

Scientists are now convinced to conclude as to how the plates move and how such movements relate to earthquake activity. Most of the movements occur along narrow zones between plates where the results of plate-tectonic forces are most evident. There are four types of plate boundaries:

- **Divergent boundaries:** Where new crust is generated as the plates pull away from each other.
- **Convergent boundaries:** Where crust is destroyed as one plate dives or subducted under another.
- **Transform boundaries:** Where crust is neither produced nor destroyed as the plates slide horizontally past each other.
- **Plate boundary zones:** Broad belts in which boundaries are not well defined and the effects of plate interaction are unclear.

Divergent boundaries occur along spreading centres where plates are moving apart and new crust is created by magma pushing up from the mantle. The crust often subsides, forming a "rift valley" similar to what is happening today in the Great Rift Valley through the Red sea which is currently widening at the rate 3 cm. /year. If rifting continues, a new plate boundary will form by the process of seafloor spreading. Mid-ocean ridges, undersea mountain chain, are the locus of seafloor spreading and are the sites where new oceanic lithosphere is created by the upwelling of mantle "asthenosphere". Sea floor spreading over the past 100 to 200 million years has caused the Atlantic Ocean to grow from a tiny inlet of water between continents of Europe, Africa and the America into the vast ocean that exists today.

Subduction zones along the leading edges of the shifting plates form a second type of boundary, the convergent boundary where the edges of lithospheric plates drive steeply into the earth and are reabsorbed at depths of over 640 km. Earthquake foci form steeply inclined planes along the subduction zones, extending to depths of about 710 km. The world's most destructive earthquakes occur along subduction zones.

Continental mountain ranges are formed as a result of continental-continental convergence. For example, the Himalayas (8,854 meters above sea level) are still rising as the plates carrying India and Eurasia come together. Mountains are also formed when ocean crust is subducted along a continental margin, resulting in melting of rock, volcanic activity and compressional deformation of the continent margin. As asthenosphere consists of molten rock of a density greater than the density of iron in crust, the lighter rock on the crust float on asthenosphere, so that the higher the mountain the deeper its base extends into the core. (Which are referred as pegs in Quranic terms).

A third type of boundary called transform boundary occurs where two plates slide past one another in a grinding, shearing manner along great faults called strike-slip faults or fracture zones along which the oceanic ridges are offset.

Lithospheric plates are constantly shifting position on the surface of the globe, and as they are carrying continents with them, such continents are also drifting away or towards each other.

Quranic Confirmation

A study of the Holy Quran about the creation and structure of the earth reveals that the physical phenomenon of earth's geology and its significance is mentioned in many verses and invite all to observe, think and discover the structure and natural laws. For example in 12/86 Quran states, "And by the Earth that has its own fault". The meaning of this verse encompasses such geological terms as "Fissures", "Faults" and "Rifting". Verse 04/13 states, "And there are on Earth (many) tracts of land close by one another, and yet widely differing from one another". This clarifies the phenomenon of plate boundary condition.

SEISMOLOGY

Seismology

The scientific study of earthquakes and related phenomena, including the propagation of waves and shocks on or within the earth by natural or artificially generated seismic signals is termed as seismology.

Seismic Waves

As a result of earthquake, several type of waves are generated including primary or P waves which are longitudinal, compressional and travel fastest. These waves shake the ground back and forth in the same direction and in the opposite direction of the direction the waves are moving. They cause little damage. Secondary or S waves which are transverse, i.e., they cause the earth to vibrate perpendicularly to the direction of their motion. S, waves are slow in movement and are much more destructive than P, waves. They are of the shear type having oscillation at right angle to the path of travel. The oscillation may be horizontal and vertical.

P and S waves after one reflection are called PP and SS and so on. Sometimes P waves reflect as S waves, then they are designated as PS wave. In 1885, Lord Raleigh described a type of surface wave which travels along the surface of a homogeneous elastic solid. This type of wave called R wave, was first observed in about 1930.

Q waves, or Love waves, were predicted by an English mathematician, Love. They move transversely on the surface without vertical oscillation. Surface waves consist of several major types and are called long or L waves. Since the velocities of the P and S waves are affected by changes in the density and rigidity of the material through which they pass the boundaries between the regions of the earth known as the crust, mantle, and core have been discerned by seismologists and scientists who deal with the analysis and interpretation of earthquake waves.

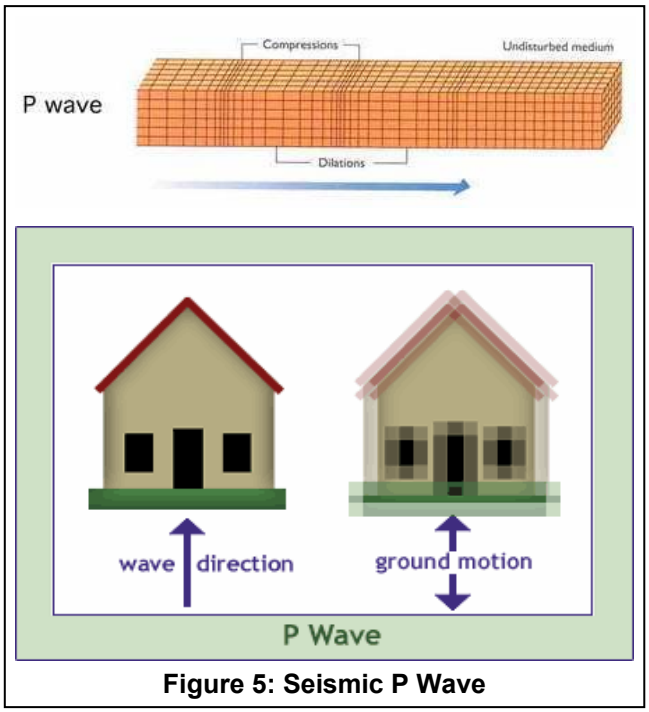


Figure 5: Seismic P Wave

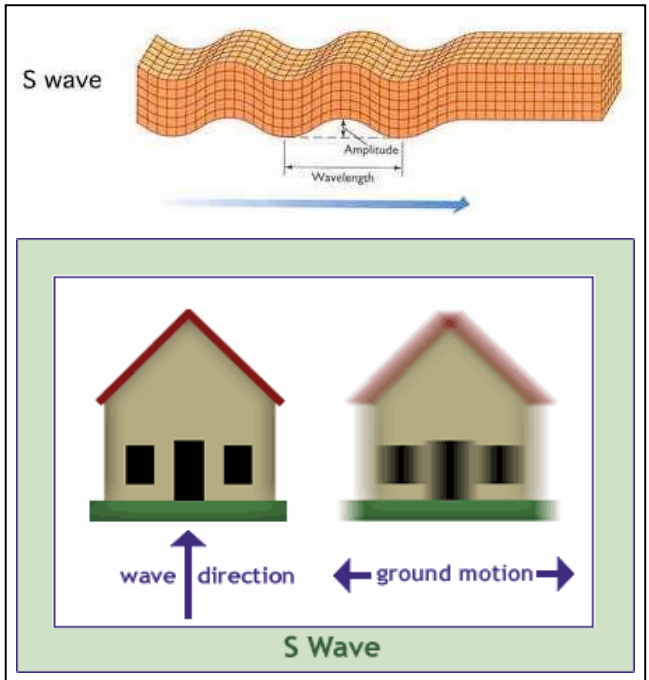


Figure 6: Seismic S Wave

Seismographs

Instruments used to detect and record seismic disturbances (P, S and L waves) are known as seismographs. The components of ground movement are simultaneously recorded.

- Vertical movement
- Horizontal North-South movement
- Horizontal East-West movement.

From these records of the component movements actual movements are reconstructed and wave trains are separated into definite pattern. Periods, acceleration and amplitude of vibration can then be determined.

Such a study implies that the disappearance of S waves below the depth of 2,900 km indicate that at least the outer part of earth's core is liquid. In 1935 the American seismologist, Charles F. Richter (1900-1985) invented the Richter scale to determine an earthquake magnitude and later improved by Gutenberg and Richter. Each successive point on the logarithmic scale represents an increase by a factor of 10 in the wave amplitude. The energy released in an earthquake can easily be approximated by an equation that includes this magnitude and the distance from the seismograph to the earthquakes epicentre.

$$\text{Log } E = 11 + 1.6M$$

Numbers on the Richter scale range from 0 to 9. An earthquake whose magnitude is greater than 4.5 on this scale can cause damage to the buildings and other structures. Severe or major earthquakes have magnitude greater than 7.0.

The Italian seismologist "Giuseppe Mercalli" developed the Mercalli scale, which is used to measure the severity of an earthquake in terms of its effects on the inhabitants of an area, e.g. how much damage it causes to buildings.

The grading of earthquakes with respect to their magnitudes and frequency of their occurrence is as following:

- **Great earthquakes : 8.0 or higher - once a year**
- **Major earthquakes : 7.0 to 7.9 - 18 times a year**
- **Strong earthquakes : 6.0 to 6.9 - 134 times a year**
- **Moderate earthquakes : 5.0 to 5.9 - 1319 times a year**
- **Light earthquakes : 4.0 to 4.9 - 13000 times a year**
- **Minor earthquakes : 3.0 to 3.9 - 130,000 times a year**
- **Very minor earthquakes : < 3.0 - 1.3 millions times a year**

MAJOR EARTHQUAKES

Some of the major earthquakes in the past 100 years are as following:

Table 1: Major Earthquakes in Past 100 Years

NO	LOCATION	YEAR	MAGNITUDE	CASUALTIES
1.	Gansu, China	1920	8.6	200,000
2.	Tokyo, Japan	1923	8.0	143,000
3.	Quetta, Pak.	1935	7.6	60,000
4.	**Chile (1960)**	1960	**9.5 Largest**	2000
5.	Turkey	1999	7.4	17,800
6.	India, Gujrat	2001	7.7	20,000
7.	Iran, Bam	2003	7.5	30,948
8.	Hebci, China	1976	7.5	255,000
9.	Kobe, Japan	1995	6.69	
10.	Indonesia, Philippines, India, earthquake accompanied by Tsunami	2004	9.0	>200,000
11.	Pakistan (Northern areas), Azad Kashmir	8/10/2005	7.6	>100,000

Figure 7: Hanshin Expressway Japan

Figure 8: A Building after Earthquake, Kob

Figure 9: Aerial View of Azad Kashmir after Earthquake

Figure 10: Rescue Operation at the Site of Toppled Margalla Tower in Islamabad

EFFECTS – RISKS AND HAZARDS

Effects Of The Earth Movement

As a result of the earthquake the ground under the structure moves rapidly back and forth following the law of simple harmonic motion imparting acceleration, $a = 4\pi^2 A / T^2$ to the base of the structure where A is a amplitude of the movement and T is the period of one complete oscillation in seconds.

If the structure is completely rigid, an inertia force or earthquake force F=m.a is generated in the structure. Where F=w/g.a = w.a/g. The ratio a/g is called seismic factor.

Normally a = acceleration due to earthquake is taken as some fraction of the acceleration due to gravity, g (0.1, 0.2, 0.3 etc.). The kinetic energy in simple harmonic motion is: $K.E = Wa^2/2g\ (4\pi^2 n^2)$ where n = frequency of vibration. This equation indicates that Kinetic energy varies directly with the square of acceleration, a, and inversely with the square of the frequency, n. This implies that the acceleration alone is not sufficient measure of the destructive power of vibration. For the same value of acceleration, smaller the frequency, more K.E. is produced.

Since the real structures are not completely rigid, the actual forces generated will differ from the value (F = ma), depending upon the matching of the period of the building and the dominant period of the earthquake. Further more, the determination of the force, f, becomes more complicated because any given earthquake contains a wide and unpredictable range of frequencies and intensity of base acceleration. In general, the shorter a building is, the higher its natural frequency and taller the building is, the lower is natural frequency and higher is its natural period. **Buildings suffer the greatest damage from ground motion at a frequency close or equal to their own natural frequency, because the building and the ground motion are then in resonance with one another.**

Acceleration Response Spectrum

If a series of structures of varying periods of vibrations, represented by the damped inverted pendulums, are subjected to a given earthquake, the maximum acceleration of each structure during the earthquake can be computed and plotted against the period of the structure as shown in the Figure 11. Such a graph is known as an "acceleration response spectrum". The vertical axis is called the "spectral acceleration". Response spectra are very important "tools" in earthquake engineering.

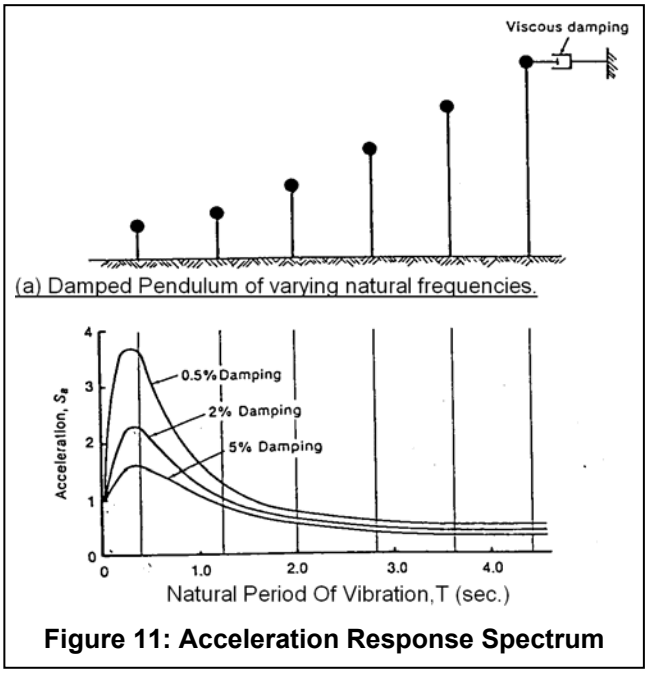


Figure 11: Acceleration Response Spectrum

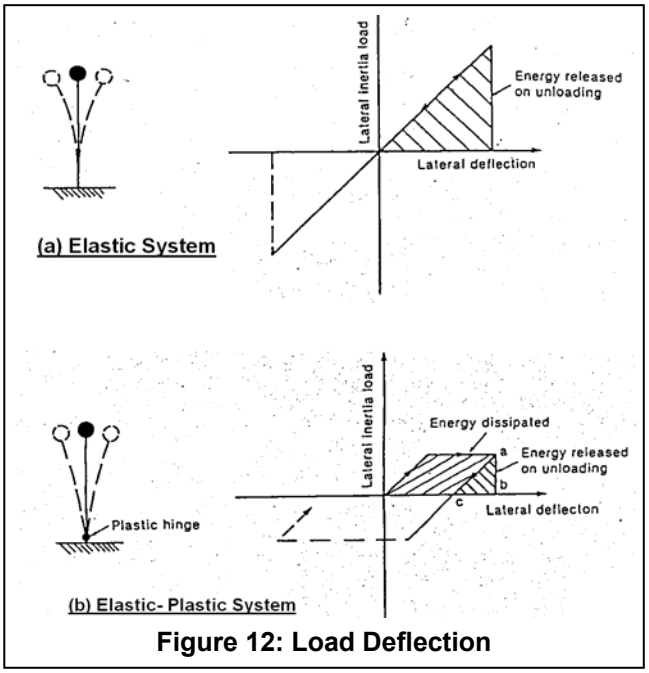


Figure 12: Load Deflection

From these curves, Sa=1, represents the maximum ground acceleration during the particular earthquake being studied. If Sa=2, for a structure of a given period, the structure experiences an acceleration twice that of the ground.

Each of the curve in Figure 11 refers to a particular degree of damping. Typically, a reinforced concrete building has 1 to 2% damping prior to an earthquake. As cracking and structural and non-structural damage develop during the earthquake, this increases to about 5%. As the damping increases, the spectral acceleration decreases.

Figure 11 suggests that for the buildings having short fundamental periods, the maximum acceleration may be several times the ground acceleration. As discussed earlier, the severe earthquakes may have maximum ground accelerations on the order of 0.2g to 0.4g, this implies that the horizontal earthquake force could be as large as or larger than the weight of the building, if the building remains elastic. The graph helps identifying the resonant frequencies at which a building will undergo peak acceleration, which is a very important factor in designing the building to resist earthquake.

Fortunately, the inelastic action in the structure tends to dissipate the earthquake forces, as such in design of the buildings for earthquakes, smaller forces are encountered than the forces, theoretically discussed above.

Effect Of Ductility

The effect of ductility can easily be evaluated by comparing the load deflection diagrams for an elastic structure and an elastic-plastic structure subjected to the same lateral deflection. In Figure 12a an undampened elastic pendulum is deflected to the right, energy is stored in it in the form of strain energy. The stored energy is equal to the shaded area under the load deflection diagram of Figure 12a. When the pendulum is suddenly allowed to move back to its original position, this energy reenters the system as velocity energy and helps drive the pendulum to the left. This pendulum oscillates back and forth along the load deflection diagram.

If the pendulum is provided with a plastic hinge at its base, the load-deflection diagram for the same lateral deflection would be as shown in Figure 12b. When this pendulum is suddenly allowed to move back to its original position, only the energy indicated by the triangle a-b-c reenters the system as velocity energy, the rest being dissipated by friction, heat and crack developments etc.

Figure 13 compares the load deflection diagram for an elastic structure and an elastic-plastic structure subjected to the same lateral deflection Δu. The ratio of the maximum deflection Δu to the deflection at yielding Δy is defined as the "Displacement Ductility Ratio,μ.

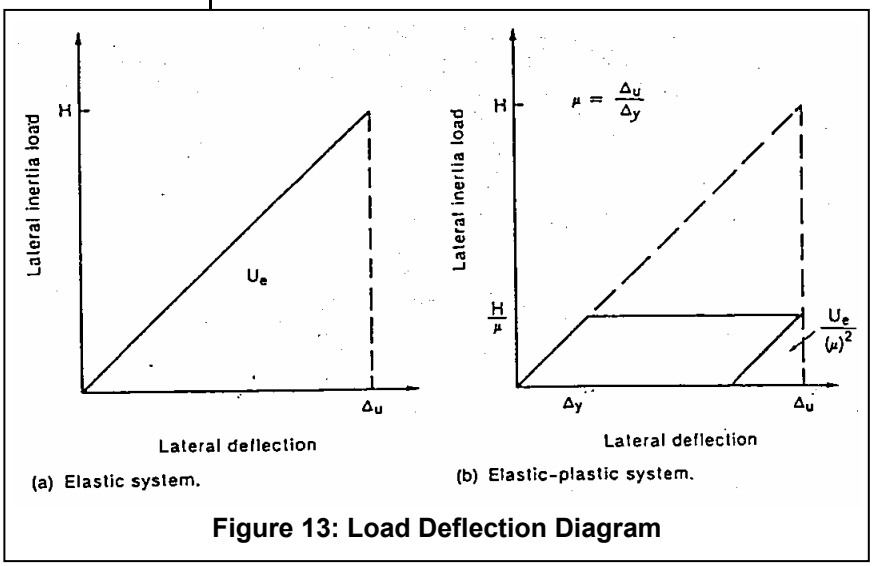


Figure 13: Load Deflection Diagram

$$\mu = \frac{\Delta u}{\Delta y}$$

It is evident from the Figure 13 that for a ductility ratio of 4, the lateral load acting on the elastic-plastic structure would be $1/\mu = 1/4$ of that on the elastic structure, and the energy recovered in each cycle would be $1/\mu^2 = 1/16$ as low as in elastic system. It implies that if a structure is ductile it can be designed for lower seismic forces.

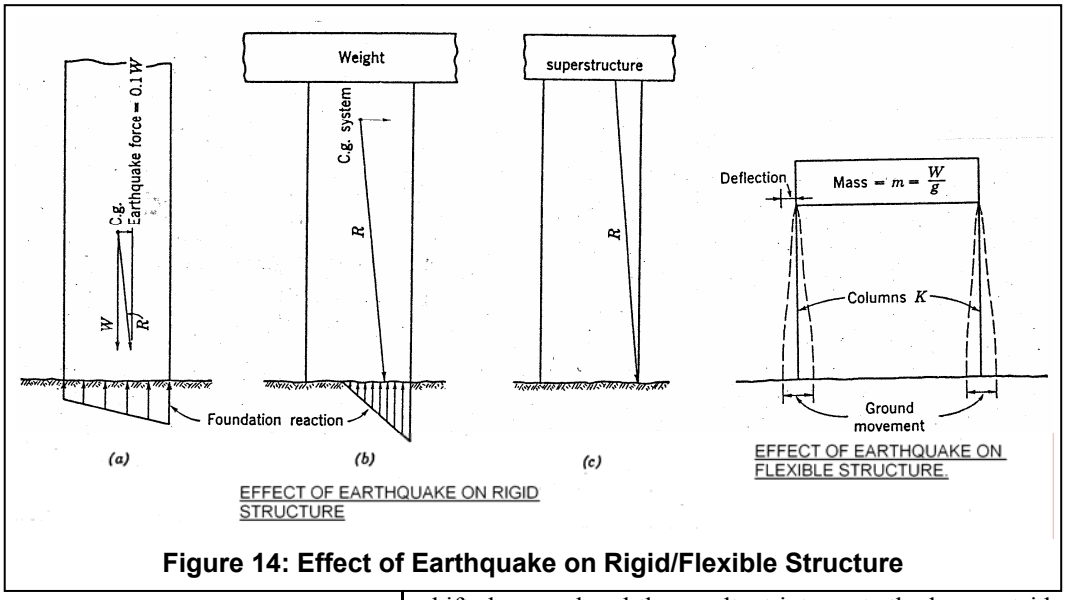


Figure 14: Effect of Earthquake on Rigid/Flexible Structure

Effect Of Rigid And Flexible Structure

In case of rigid structure, when the resultant of gravity load and lateral load passes through the middle third of the base, there is no danger to the stability of the structure as in case "a" hereunder. In case "b", the c.g. of the system is shifted upward and the resultant intersects the base outside the middle third. The structure may need anchorage. In case "c" the resultant intersects the base practically on its edge. The structure is unsafe. In flexible structure the ground will oscillate back and forth under the mass but the shear force applied to the legs at the foundation and to the body at the top will not be determined by w.a/g. The shear force on each leg in this case will be equal to the shear induced by a deflection equal to earthquake amplitude.

SAFETY PRECAUTIONS

Special Provisions For Seismic Design Of Buildings

The American design codes require that the buildings should not collapse under the strongest earthquake anticipated at the building location. This earthquake is taken as one with a 10% chance of excedance in 50 years.

For the safe design of the structure against the earthquake motion, the following four main steps are to be followed:

i. Seismicity of the region.
ii. Seismic performance category (ASCE.7-95).
iii. Establish a definite design criteria.
iv. Building configuration.

The performance criteria including major categories are:

- Strength
- Stability
- Ductility
- Lateral deflection
- Cracking

i. Seismicity

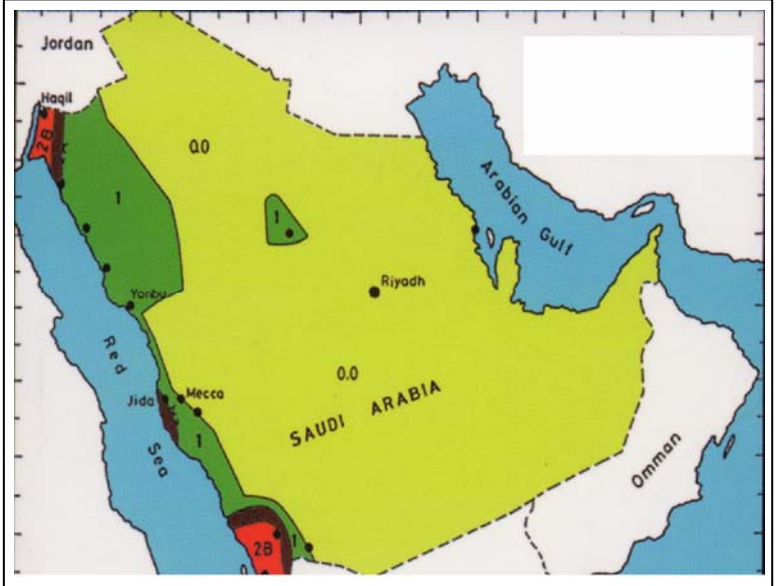


Figure 15: Seismic Map of Saudi Arabia

ii. Seismic Performance Categories (ASCE.7-95)

Table 2: Seismic performance categories (ASCE.7-95)

Value of Av	Equivalent Z factor (UBC)	Equivalent R-Scale	USE categories			Remarks
			I or II	III	IV	
Av < 0.05	0	≤ 4.9	A	A	A	The values of Av are given for sites on rock. For other soil condition Av is multiplied by site coef. 0.8 to 3.5 to get the seismic coefficient.
0.05 ≤ Av < 0.10	1	5.0 to 5.9	B	B	C	
0.10 ≤ Av < 0.15	2A	6.0 to 6.9	C	C	D	
0.15 ≤ Av < 0.20	2B	7.0 to 7.9	C	D	D	
0.20 < Av	3 or 4	8.0 & above	D	D	E	

Table 2, suggests "a seismic performance category" ranging from A for low seismic hazard, corresponding to low values of Av, to E of "Use category" IV buildings in high seismic areas.

iii. Definite Design Criteria

- Lateral forces in compliance with ASCE.7-95 and UBC (1628)
- Factor of safety
- Unit stresses
- Soil profile type and site coefficient (UBC).
- Method of analysis of each structure

For design purpose, the lateral load is converted to lateral forces at each storey level. These are selected to simulate the distribution from a modal analysis. For building periods of 0.5 sec. or less, buildings of upto 6 or 7 storeys, first-mode vibration dominates and the lateral force distribution approaches an inverted triangle. For very tall buildings higher vibration modes are significant and the equivalent lateral force distribution approaches a parabola with apex at the base of the building. The shear, Vx in any storey x is the sum of the lateral forces acting above that storey.

$$Vx = \sum_{i=x}^{n} Fi$$

Where n refers to the top level.

N.B: Specific details on any of these calculation procedures are available in the applicable building codes or in books on earthquake engineering. For example U.B.C (Section 1629 and 1630 discusses with the Dynamic lateral force procedure and lateral force on equipment supported by the structure respectively needs proper attention.

iv. Building Configuration

The choice of the building configuration is the most important factor in the design for seismic load. It helps to select the distribution of masses and stiffness in the building and the choice of the load path by which lateral loads will eventually reach the ground. The uniform building code (UBC) defines the buildings as "regular" or "irregular"

The major irregularities are as following:

a) Soft storey

Large concentrated masses or abrupt changes in mass, stiffness, or strength from storey to storey.

These should be avoided because they attract large forces and localized damage. The "soft storey" created by terminating or greatly reducing the stiffness of the shear walls in the ground storey concentrates forces and deformations at this level.

b) Discontinuous shear walls

The structural system should be such as to provide a number of continuous load paths to transmit horizontal loads to the foundations. The building shown in Figure 16a has discontinuous shear walls at each end which rely on the floor members AB and CD in the first floor to transmit the shears to the walls in the ground floor. The rocking of the upper part of the building puts excessive loads on these floor members. Shear walls which have in-plane discontinuities Figure 16c should also be avoided.

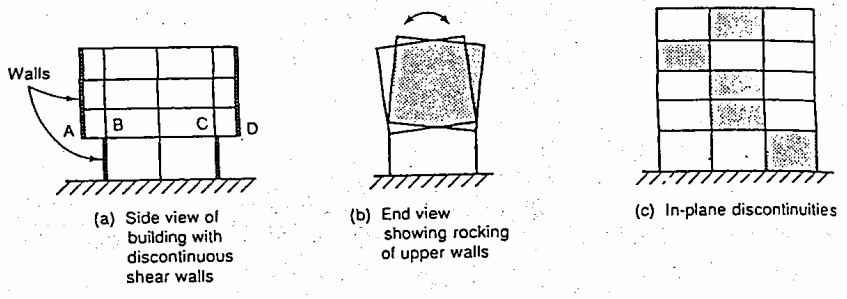


Figure 16: Discontinuous Shear Walls

c) Large eccentricities

The building should be symmetrical with respect to forces acting on it or, if not, the distance between the centre of mass, the point through which the seismic forces act on a given floor, and the centre of resistance i.e. eccentricity should be minimized. If there is an eccentricity, as shown in Figure 17, the building will undergo torsional deflection as indicated. Due to this deflection, the column at A, in Figure 17, will experience larger shears than those at B.

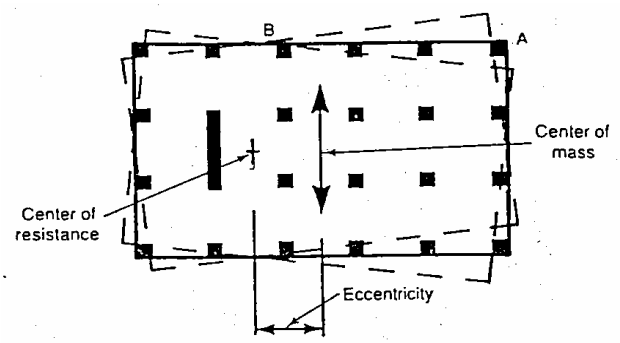


Figure 17: Eccentricity of Earthquake Forces

d) Low torsional stiffness

The building should be provided with structural members having significant torsional resistance. The individual walls in Figure 18b, are symmetrical and farther from the centre of rotation than in Figure 18c, they provide more torsional resistance. The plan in Figure 18d is particularly unsuitable as it has large eccentricity and very little tersional resistance.

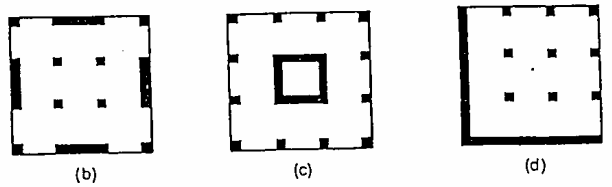


Figure 18: Design of Earthquake Resistance

e) Vertical and horizontal geometric irregularities

The two parts of each of the buildings shown in Figure 19 have different periods of vibration and severe damage can occur where they are joined together. For the building on the left, one solution is to separate the two wings with a joint, wide enough, so that the two wings can vibrate separately without banging together. In case this is not practical, the corner region must be strengthened to resist the tendency to pull apart.

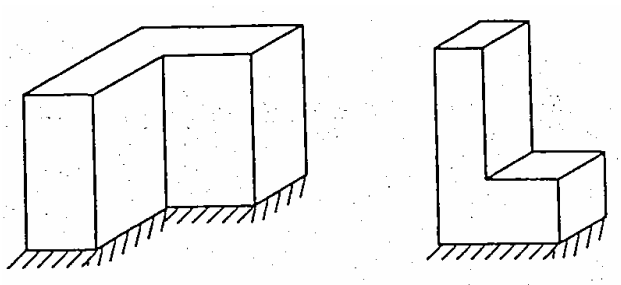


Figure 19: Vertical & Horizontal Irregularities

f) Variations in column stiffness attract forces to the stiffer columns

Column D in Figure 20 would be four times as stiff as column "A" for the same cross-section and would initially be called on to resist four times the shear. Frequently, such a column will fail in shear above the wall.

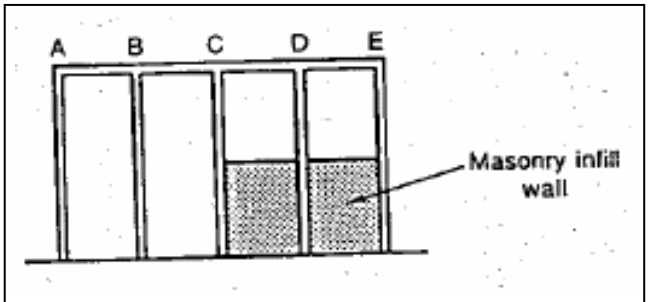


Figure 20: Variations in Column Stiffness

g) Diaphragm discontinuities

Figure 21 shows a plan view of a floor diaphragm transmitting seismic forces to shear walls at the ends. The diaphragm acts as a wide flat beam that develops tension and compression on its two sides. Abrupt discontinuities or changes of stiffness of floor diaphragms such as the notch in the diaphragm in Figure 21, lead to a concentration of damage in the weak area.

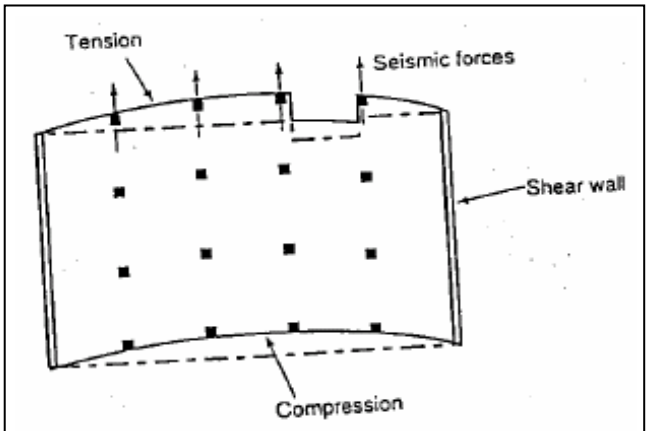


Figure 21: Diaphragm Discontinuities

h) Nonparallel forces resisting system

If the frames or walls that resist the lateral loads are not parallel to or symmetrical about, as shown in Figure 18d, major torsional effects may be introduced. Further, horizontal and vertical irregularities are described in table's 16-L and 16-M of UBC.

REQUIREMENTS OF THE BUILDING CODES

Structural System And Height Of The Buildings

Various reinforced concrete structural systems and allowable building heights for various type of "Seismic performance category" are recommended in Table 19-2 of ASCE.7-95 and Table 16-N of UBC-94. Accordingly, the structural system is classified as following:

Bearing Wall System

It is a system of floors supported by walls that resist both the gravity and lateral loads. For resistance to lateral loads, shear walls or braced frames are required.

Building Frame System

This comprises of a space frame (column and beam frame) which supports gravity loads. Lateral loads are resisted by shear wall or braced frames.

Moment Resisting Frame

It is designed to resist both gravity and lateral loads. Lateral load is resisted by the flexural action of the members.

Dual System

It is a combination of a space frame resisting both gravity and lateral loads and a shear wall resisting lateral loads. The two systems shall be designed to resist the total design base shear in proportion to their relative rigidities considering the interaction of the dual system at all levels.

It is evident from the table 19-2 (ASCE) and Table 16-N (UBC) that ordinary moment frames are not permitted in zones 2A, 2B, 3 and 4.

Codes Provision For Seismic Resisting Members In Frame

ACI code chapter 21 gives special requirements for design and construction of reinforced concrete members for seismic resistance.

a) In regions of moderate seismic risk, reinforced concrete frames resisting forces induced by earthquake motions shall be proportioned to satisfy section 21.8 of chapter 21 in addition to the requirements of chapter 1 through 18 (ACI).

b) In regions of high seismic risk, all reinforced concrete structural members shall satisfy 21.2 through 21.7 of chapter 21 in addition to the requirements of chapter 1 through 17, as outlined in the Table 3.

The notations used in the Table are as below:

OMF = Ordinary moment frame
IMF = Intermediate moment frame
SMF = Special moment frame
* = Moderate earthquake risk (Zone # 2)
** = High earthquake risk. (Zone # 3 & 4)

c) Earthquake resistant design evaluation:

According to ACI section 21.3, the flexural members of frames should satisfy the following conditions in performance categories D & E.

1. Factored axial compressive force on the member shall not exceed (Ag. fc'/10)

Table 3: Sections of ACI Chapter 21 to be satisfied

	Seismic Performance Category			
	A	B	C*	D and E**
Frame members resisting earthquake effect in moment resisting frames.	None (OMF)	• None (OMF) • ASCE.7-95 requires some continuous beam bars. • Moment frames on soil other than stiff soil: 21.8	21.8 (IMF) columns supporting discontinuous walls must have closely spaced ties.	21.2 to 21.7 (SMF)
Walls and diaphragms resisting earthquake effects.	None	None	None	21.2, 21.6
Frame members not resisting earthquake effects.	None	None	None	21.2, 21.7, 21.8.2

2. Geometric limitation:

   i) Clear-span to its effective depth ratio should be ($l_n \geq 4d$) to avoid deep beam action.
   ii) The width-to-depth ratio shall not be less than 0.3 ($b/d \geq 0.3$).
   iii) The width of the member should not be either less than 10 inch (25 cm) or more than the width of the supporting member plus (3/4) times the thickness on either side.

3. Flexural reinforcement must satisfy detailing requirements of ACI, sec. 21.3.2 to provide adequate ductility:

   i) At least two brass must be provided continuously top and bottom.
   ii) The areas of each of the top and bottom reinforcement at every section shall not be less than given by equation (10-3) of ACI code, nor less than 200 bw.d/fy. The reinforcement ratio, p=As/b.d, shall not exceed 0.025 for either top or bottom reinforcement. Normally, p would not exceed about 0.015.
   iii) The positive movement strength at the face of beam column joint shall not be less than half the negative movement strength. This provides p = 0.5p and greatly improves the ductility of the end of the beams.
   iv) At every section the positive and negative movement capacity shall not be less than one fourth the maximum movement capacity provided at the face of either joint.

4. ACI section 21.3.2.3 prohibits lap splices at the following locations:

   i) Within the joints
   ii) Within a distance of twice the member depth from the face of the joint and
   iii) In locations where flexural yielding can occur due to lateral deformations of the frame.
   iv) Where lap splices is permitted, it must be enclosed by hoops or spirals at the smaller of 4 inc (10 cm) or d/4 welded splices and mechanical connections conforming to section 21.2.6.1 (ACI) is permitted. Tack welding of bars is not permitted.
   v) Welding of stirrups, ties, inserts, or other similar elements to longitudinal reinforcement required by the design is not permitted.
   vi) Transverse reinforcement or hoop shall be provided in compliance with section 21.3.3 (ACI). This reinforcement is required primarily to confine the concrete and maintain lateral support for the reinforcing bars in regions where yielding is expected.
   vii) Longitudinal and transverse reinforcement in columns should confirm to the requirement of the section 21.4.3 and 21.4.4 of ACI.
   viii) Joints of the frame shall be designed in compliance with the section 21.5

5. Requirements for frames in regions of moderate seismic risk:

   The requirements of ACI section 21.8 should be implemented.

USE OF MODERN TECHNOLOGY

1. Elastomeric bearings (unidirectional or multidirectional)
2. Seismic connectors

- Proper disposition of seismic connector and bearings will help to restrain the displacement and stresses will be transferred to the vertical members.

CRISIS MANAGEMENT

In order to reduce death, injuries, property damage, economic losses and human suffering caused be natural disaster like earthquake, a comprehensive, well organized and systematic approach to crisis management is vital. The first stage of this programme is to provide immediate relief to the sufferers and to execute the rescue and recovery operations.

Rescue

Pakistan lacks in resources and knowledge to handle the crisis in any hazardous situation. In the last 200 years there have been five major earthquakes in the 2,100 kilometres of Himalayan range. But Pakistan never seriously prepared itself for such eventualities although it is located in a high risk zone.

For immediate rescue operations every city and town of the country should be equipped with the following facilities:

1. Life sensors
2. Concrete and steel cutting tools
3. Portable welding plants
4. Cranes, and earthmoving equipments
5. Generators

6. Trained technicians in all disciplines, specially in power and water distribution
7. First aid facility.
8. Fire-fighting equipment.

Relief And Recovery

For prompt relief and recovery of the affected people, arrangement for the following material, equipment and manpower should immediately be provided:

1. Potable water bladders or bottles
2. Food (Tin food)
3. Medicine and medical facilities
4. Tents, blankets, and dresses
5. Doctors, psychologist, sociologist, medical technicians, engineers and public health workers
6. Generators
7. Ambulances
8. Helicopters

Rehabilitation

Reconstruction

The assignment will extend its scope to rebuilding the villages and cities in terms of:

1. Housing
2. Civil amenities
3. Utilities
4. New infrastructure (school, colleges, university, hospitals, road, bridges and office buildings etc.)

While planning and designing for the new houses and buildings, one should bear in mind that, "it is buildings rather than nature that are responsible for death on a large scale during an earthquake".

In the affected areas in Pakistan and Azad Kashmir, it is the buildings, the concrete structure haphazardly constructed, uncontrolled and under-designed or badly designed structure, which have killed thousand of adults and children. In this regard nature is only partly to be blamed for loss of life and property.

In case of Margalla tower tragedy in Islamabad, nature played little part in the fall of this building and big responsibility for killing of the unfortunate occupants and loss of property falls on the shoulder of the designer, the builders and authorities responsible for approval and supervision.

Margalla tower should be a final warning to all in Pakistan, in every city and town, who are building their own homes or buying houses and flats and also a final warning to the authorities who control the building affairs.

It is therefore imperative that minimum earthquake resisting building code be compiled with due consideration of local and regional geology, available raw materials, needs and culture and be strictly enforced throughout the country for all new construction to help minimize loss of human life and harm to infrastructure in case of a future calamity.

Psychological Rehabilitation

People who have been victims of earthquake disaster suffers from grave psychological problems, some of which are:

1. Immediate effects:
   - Shock
   - Intense anxiety, fear, terror
2. Long-term effects:
   - Feel helpless and hopeless
   - Incapable of making decision
3. Other emotional effects:
   - Hostility
   - Anxiety, depression, chronic grief
   - Suspiciousness, nightmares
4. Women and children (5 to 10 years old) are most vulnerable to suffer past traumatic disorders.
5. Treatment:
   - Stress management
   - Individual therapy
   - Family therapy
   - Discussion groups
   - Antidepression medication

CHALLENGES & RESPONSE

Challenges in Rescue, Relief and Recovery Operation

A prompt, well coordinated and efficiently controlled programme is vital for such operations.

Response of Pakistani Nation

The reorganization by a society of its social problems is highly selective process. The Pakistani nation, as we all know, has risen magnificently to the occasion and helped with every possible relief and assistance. Private individuals, N.G.O's and religious and political parties were the first to be in the disaster hit areas.

International Aid

On international arena with the exception of Islamic and Muslim countries like Saudi Arabia, U.A.E., Kuwait, Iran & Turkey, the world failed to grasp scale of South Asian quake disaster, which killed more than 100,000 people and left more than 4 million homeless in difficult mountain

territory. It is worth mentioning that 70% of the total aid was given by Islamic countries.

Determination

We have to live with the effect of this disaster for years to come. So more important thing is to ensure that the feelings of common nationhood aroused by this disaster does not diminish. We should be determined to resist with the "donor fatigue" and also with the "compassion fatigue". This requires sincere, energetic and wise leadership and steps stirring enough to catch the popular imagination.

CONCLUSION AND RECOMMENDATION

1. Earthquakes occur all over the world almost every day.
2. The net effect of the active fault in any region is the probability of occurrence of an earthquake.
3. We cannot prevent earthquake, but

We can SIGNIFICANTLY MITIGATE their effects by:

- Identifying hazards
- Building safe structures
- Implementation of the building codes which should be upgraded with the consideration of the local geology and available raw materials.
- Providing education
- Enforcement of crisis management for a prompt rescue, relief and recovery operation.

The recent tragedy in Pakistan reminds us that a more organized and systematic approach to crisis management is vital in any civilized society. Methods and procedures to be adopted in planning, scheduling, controlling and organizing the Rescue, Relief, Recovery and Rehabilitation activities need to take into consideration:

- Mountainous terrim
- Logistic problem
- Resource constrain
- Weather
- Inadequate aid

Pakistani nation has volunteered every possible aid and services as a part of the national effort to provide relief and assistance to the victims of the worst ever natural disaster in Pakistan and Azad Kashmir. We need to enhance our efforts and to ensure that the momentum is not lost.

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CHARTERED UNIVERSITIES / DEGREE AWARDING INSTITUTES
IN PUBLIC SECTOR

	CHARTERED UNIVERSITY / DEGREE AWARDING INSTITUTE	ESTABLISHED ON
1.	Air University, Islamabad (http://www.au.edu.pk)	29th October 2002
2.	Allama Iqbal Open University, Islamabad (http://www.aiou.edu.pk)	25th May 1974
3.	Bahauddin Zakariya University, Multan (http://www.bzu.edu.pk)	4th March 1975
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6.	Balochistan University of Info. Technology and Man. Sciences, Quetta (http://www.buitms.edu.pk)	18th July 2002
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8.	Dow University of Health Sciences Karachi (http://www.dumhs.com)	29th December 2003
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51.	University of Malakand, Chakdara, Dir. Malakand	27th October 2001
52.	University of Peshawar, Peshawar (http://www.upesh.edu)	30th October 1950
53.	University of Sargodha, Sargodha (http://www.uos.edu.pk)	16th November 2002
54.	University of Science & Technology, Bannu	6th August 2005
55.	University of Sindh, Jamshoro (http://www.usindh.edu.pk)	1947
56.	University of the Punjab, Lahore (http://www.pu.edu.pk)	1882
57.	University of Veterinary and Animal Sciences, Lahore	8th June 2002
58.	Virtual University of Pakistan, Lahore (http://www.vu.edu.pk)	11th September 2002

50 Chartered Universities and 8 Degree Awarding Institutes in Public Sector **Total 58**

PRINCIPLES AND APPLICATION OF INSULATION TESTING WITH AC

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ABSTRACT

The first part of this paper was published in the IEP-SAC Journal, 2004-2005 with the title "Principles and application of Insulation Testing with DC". The common insulating materials, their application and desirable properties, basic initiators of insulation degradation and causes of insulation failure were discussed in the first part of paper. This paper discusses testing techniques with AC, reviews various types of AC insulation tests and finally highlights analysis of test results.

INTRODUCTION

Electrical insulation is a medium or a material which, when placed between conductors at different potentials, permits only a small or negligible current in phase with the applied voltage to flow through it. It may be solid, liquid, gas or vacuum. No insulation is perfect, so some current does flow through it. Such a current may be insignificantly small for most practical purposes but it is the basis of insulation testing.

Insulation degrades over a period of time because of various stresses imposed upon it during its normal working life. The insulation of electrical equipment is designed to withstand these stresses during the working life of insulation. Abnormal stresses can cause an increase in the natural aging process that can severely shorten the working life of the insulation.

The solid and liquid insulating materials used in a transformer are adversely affected by heat, oxygen and moisture. The life of insulation reduces in inverse proportion to the operating temperature. The effect was quantified on the basis of researches during 1950 - 1980. Two noteworthy formulae are renowned. Montsinger's formula for aging of insulation was the first formula and is called "Rule of Eight Degrees". The rule states that each 8^{o}C rise in temperature reduces the life of insulating material by a half. The second one is Arhenius formula that recognizes the degree of polymerization of cellulose during short time heavy loads. This formula is applicable in the temperature range 80 – 130^{o}C.

CIGRE's Transformer Working Group has considered 6^{o}C as the value for loading guide.

Insulation type tests prove the capabilities and guaranteed ratings. Special tests investigate certain phenomena or certain capabilities. Insulation routine tests reveal the faults in material or construction and do not impair the properties and reliability. They verify that manufacture and assembly is satisfactory. Insulation pre-commissioning tests confirm that there are no transit damages and installation is satisfactory. During service life of an electrical apparatus, regular preventive and predictive maintenance insulation tests allow to detect the reversible / non-reversible insulation problems so that most appropriate actions to be taken to correct the insulation.

TESTING TECHNIQUES

AC, DC And Very Low Frequency (VLF) Testing

Most electrical equipment in utility, industrial, and commercial power systems use either 50 or 60 Hz alternating current. Because of this, the use of an alternating current source to test insulation would appear to be the logical choice. However, insulation systems are extremely capacitive, for this and other reasons like bulky and expensive test equipments, DC was considered more suitable in the industry in the past. The DC test equipment is almost trivial in size compared with AC test equipment. For example, a one-mile length of cable being tested at 50 kV AC would require test equipment with a capacity of between 400 kVA and 500 kVA. A DC test at 50 kV would require test equipment having capacity of only 50 W. The advantage of DC testing was, the test equipment is comparatively small, light weighted, not too costly and easy to handle and operate than the corresponding AC test equipment.

When the first plastic cables were used (XLPE, PE, EPR and in the early years PVC) still DC tests were applied to those cables. However, the success of these tests in detecting faults was rather poor. Furthermore, it turned out that DC testing on XLPE cables due to extremely low dissipation factors can even be harmful to the cable due to introduction of space charges during test, which may lead to local electrical overstress after applying line voltage again. This finally leads to a breakdown of a sound cable, which was initiated by the DC test. This was the reason that, at least in Europe, DC testing on plastic cables is banned since years. In a program sponsored by the Electric Power Research Institute (EPRI) at Detroit Edison, there was positive confirmation that dc testing degraded insulation and affected the reliability of service-aged cables. The Saudi Electric Company, Saudi Arabia has banned DC testing on power cables due to its destructive effect as well. The above leads to the demand that alternatives for DC on site testing were needed to be developed. The best alternative taking into account the advantages of DC test equipment and avoiding the above described disadvantages is VLF testing. The defects in a cable can be exposed in best way by AC hi-potting it using VLF test because it is more selective and sensitive to defects compared to testing at power frequency. After any cable is installed or repaired, it should be VLF hi-potted to insure the integrity of insulation, splices, joints etc. The 60 kV VLF test set, make: High Voltage Inc. NY USA is small enough for easy portability. Also Baur, Austria has developed VLF test and diagnosis (DF&PD) system that provides three powerful diagnostic tools into one test unit.

Let us see how AC voltage affects insulation.

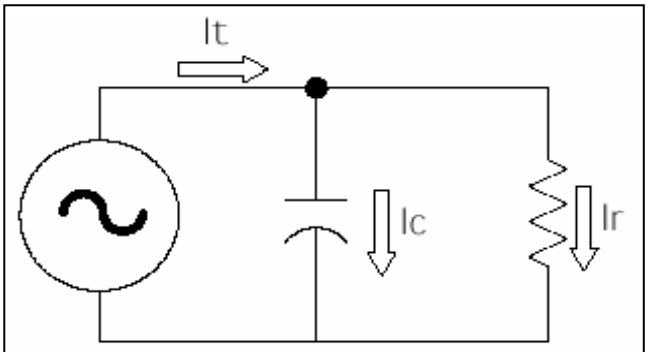

Figure 1: Insulation with an AC Voltage Applied

Insulation Current Flow (AC)

Insulation may be simply modeled as a capacitor in parallel with a resistor as shown in Figure 1. The current flow that results will comprise two components: the capacitive current (Ic) and the resistive current (Ir). Figure 2 shows the time domain graph of the two currents.

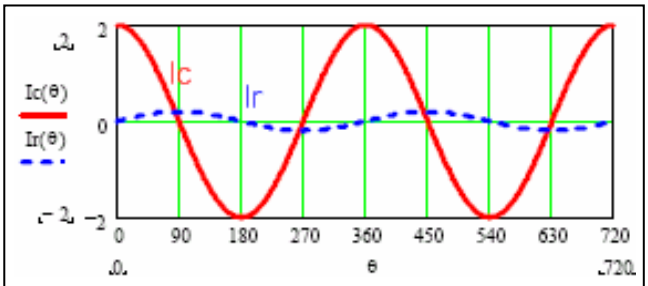

Figure 2: Insulation Current with AC Voltage Applied

For good insulation:

- $I_c \geq 100 \times I_r$
- I_c leads I_r by close to 90^o

For marginal insulation:

- $I_c \geq 50 \times I_r$
- I_c leads $I_r \leq 80^o$

TESTING INSULATION QUALITY WITH AC

Testing insulation with AC has two significant problems:

1. Since a large percentage of insulation current in both good and marginal insulation is capacitive, good insulation will have close to the same amount

of AC current flow as marginal Insulation. It is, therefore, not possible to evaluate the quality of insulation by simply measuring the magnitude of current flow.

2. The high amount of current flow drawn by the insulation requires a large test instrument to supply it. This causes AC test sets to be heavier and more difficult to transport than equivalent capability DC or VLF test sets. In spite of these limitations many manufacturers specify that AC be used to test their equipment, and AC testing has a large following.

INSULATION TESTS WITH AC

The following approaches are used for testing insulation with AC:

1. Power frequency voltage dry withstand test
2. Power frequency voltage wet withstand test
3. Separate source voltage withstand test
4. Dielectric test on auxiliary and control circuits
5. AC induced over voltage test
6. Step-up or induced voltage test
7. Insulation capacitance and dissipation factor (C & DF) test
8. Partial discharge (PD) test
9. VLF test
10. Capacitive canceling system or resonant test

These tests are discussed below in detail.

Power Frequency Voltage Dry Withstand Test

This test is part of routine test. In this test a dry, power frequency voltage is applied to the insulation, phase to ground for one minute. The test shall be made according to IEC60060-1 and to IEC 60694, clause 6.2 for switchgear and controlgear. The test voltage shall be in accordance with the relevant IEC standards. The test voltage shall be an alternating voltage having a frequency in the range of 45-65 Hz. The voltage wave shape should be approximately a sinusoidal with both half cycles closely alike, and it should have a ratio of peak-to-rms values equal to the square root of 2 within ±5%.

The voltage shall be applied to the test object starting at a value sufficiently low to prevent any effect of over voltages due to switching transients. It should be raised slowly but not so slowly as to cause unnecessarily prolonged stress on the test object at the test voltage. These requirements are met in general if the rate of rise above 75% of the estimated final test voltage is about 2% per second of the test voltage. For low voltage testing up to 1000V, the rate of rise can be greater provided that there is no overshoot of the 100% level. The test voltage should be maintained for the specified time and then reduced. It should not be interrupted suddenly as this may generate switching transients that could cause damage or erratic test results. The requirements of the test are satisfied if no disruptive discharge occurs on the test object.

Recommended maximum value of field test voltages are determined by the following:

AC test voltage = 0.75 (2 x equipment maximum voltage + 1kV) (ANSI)

AC test voltage = 80% of rated power frequency voltage withstand (IEC)

Power Frequency Voltage Wet Withstand Test

The external insulation of outdoor switchgear and controlgear shall be subjected to power frequency voltage wet withstand test under the standard wet test procedure given in IEC 60060-1.

The preferred wet withstand test procedure, described in IEC 60060-1, clause 9.1 is intended to simulate the effect of natural rain on external insulation. It is recommended for tests with all types of test voltages and all types of apparatus.

For a.c. apparatus of large dimensions, such as those having Um higher than 800 kV, no appropriate wet test procedure is available at present.

Separate Source Voltage Withstand Test

This test checks the transformer insulation strength from any winding to ground and also confirms that it can withstand transient over-voltages such as those resulting from operating any switches in service. This test is performed according to IEC 60076-3, clause 11. For test voltage, refer IEC 60076-3, Table 2, Um $\leq$ 170 kV and Table 4, Um > 170 kV.

During routine test the full test voltage shall be applied for 60 seconds between all terminals of the winding under test connected together and all terminals of remaining windings, core, frame and tank or casing of the transformer, connected together to earth. During pre-commissioning test the applied test voltage shall be reduced to 80% of routine test voltage.

Consider a power transformer 132/13.8 kV, YN0yn0, 60 Hz. The applied test voltage during routine test on primary winding will be 275 kV, 60 Hz and on secondary winding 38 kV, 60 Hz. The test voltage will be applied for 1 minute. The connection diagrams for testing primary and secondary windings are shown in Figure 3 and Figure 4 respectively.

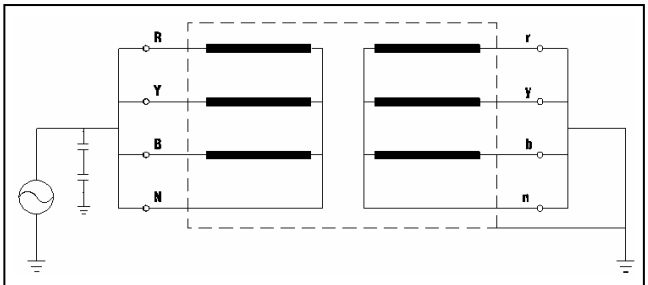

Figure 3: Connection Diagram for Primary Winding, Applied HV: RYBN – G, rybn and Transformer Tank is Grounded

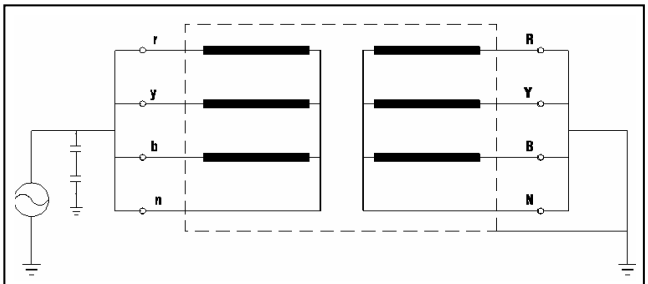

Figure 4: Connection Diagram for Secondary Winding, Applied HV: rybn – G, RYBN and Transformer Tank is Grounded

The test is successful if no collapse of the test voltage occurs.

Dielectric Test on Auxiliary And Control Circuits

Auxiliary and control circuits of switchgear and controlgear shall be subjected to short duration power frequency voltage test. The test shall be performed:

- Between the auxiliary and control circuits connected together as a whole and the frame of the switching device.
- If practicable, between each part of the auxiliary and control circuits, which in normal use may be insulated from the other parts, and the other parts connected together and to the frame.

The test voltage shall be 1 kV with duration of 1 second.

Induced Over Voltage Test (ACSD)

The induced over voltage test checks the transformer inter-turn insulation and also insulation between same part of winding and ground to withstand transient over voltage in service. The applied standard is IEC 60076-3, clause 12.2. Consider a power transformer, 132/13.8 kV, YN_0yn_0, and 60 Hz is under test. Assume a special generator of 1ø 1000HP or 3ø 2000HP 240 Hz is used so that the core does not saturate due to the higher than normal voltage that is induced in the winding. The test voltage is applied on the low voltage winding that induces specified test voltage on the high voltage winding. Test voltage is two times rated voltage of low voltage winding. If we are using a 1ø generator and test voltage is applied as per connection shown in Figure 5, then applied test voltage across r-n will be 15.93 kV (2 x 13.8 / √3 kV). If we are using a 3ø generator and test voltage is applied between terminals r-y-b-n, then applied test voltage will be 27.6 kV (2 x 13.8 kV). Test duration will be 30 Seconds [120 x (rated frequency / test frequency)]. Tapped winding shall be connected to the principle tapping.

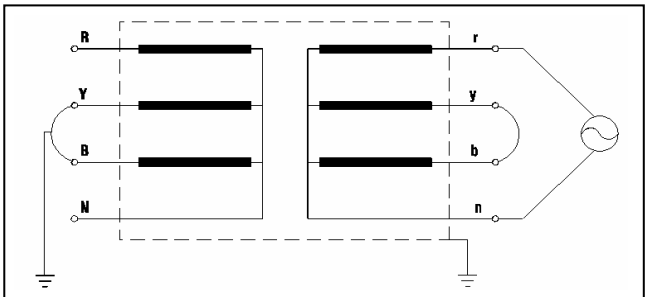

Figure 5: Connection Diagram for Induced Over Voltage Test with 1ø 1000HP 240 Hz Generator on a Power Transformer, 132/13.8 kV, YN_0yn_0, And 60 Hz

In ABB Electrical Industries Co. Ltd. Riyadh, we are manufacturing distribution transformers up to 3000 kVA and voltage ratings of 4.6, 11, 13.8 and 33 kV. We are using a 3ø, 110V, 105 kVA, 160 Hz generator along with a testing transformer 110/3000 V. Consider a distribution transformer 2500 kVA, 33/0.4 kV, Dyn11 is under test. We shall apply test voltage 800V (2 x 400V), 160 Hz for a duration of 45 seconds between terminals r-y-b-n.

Step-Up Or Induced Voltage Test

AC and DC insulation field tests cannot detect inter-turn insulation failure of a transformer. All the transformer field tests like IR, PI, DD, C&DF, TTR, winding resistance, open circuit test, short circuit test and oil (BDV, moisture, and loss tangent) will show satisfactory results. This type of fault can only be detected by step-up or induced voltage test. The test equipment consists of a 1ø, 0-240V or 3ø, 4-wire, 0-415V variable transformer (having

enough kVA rating to supply the excitation current to transformer under test), ammeters and voltmeters.

For testing a distribution transformer e.g. 13.8/0.4 kV, 1000 kVA, output of variable transformer will be connected to LV winding of transformer under test and HV winding will be kept open. The test voltage will be increased slowly and excitation current and voltage will be recorded on the test format. In case of inter-turn insulation failure, winding will saturate quickly and there will be a high excitation current. For testing a power transformer e.g. 132/13.8 kV, 20 MVA, an additional 13.8/0.4 kV distribution transformer will be required. The primary winding of distribution transformer will be connected to secondary winding of power transformer and test voltage will be applied to secondary winding of distribution transformer. The test voltage will be increased slowly and excitation current and voltage will be recorded on the test format. A fast increase in the excitation current will be a proof of inter-turn insulation failure.

Insulation Capacitance and Dissipation Factor Testing

Insulation capacitance

Measure of insulation capacitance and its dissipation factor serves as a reference for repeated measurement after the insulation tests and especially on site during installation. These are performed before applying the high voltage tests or switching-in the transformer to high voltage bus. The measurements are made with a capacitance bridge (C&DF test set) at low voltage or at 10 kV depending upon type of test set. In new insulation this type of measurement would provide indications only in the event of a serious failure.

In two winding transformer, the three insulations, high to ground, low to ground and high to low are represented by three capacitors. In order to determine the exact condition of the three insulations, six tests are conducted. These are:

1. H-XG, 2. H-G, 3. X-HG, 4. X-G, 5. H-X and
6. HX-G.

In three winding transformer, the six insulations, high to ground, low to ground, high to low, high to tertiary, low to tertiary and tertiary to ground are represented by six capacitors. In order to determine the exact condition of the six insulations, the following ten tests are conducted.

1. H-XG, 2. H-G, 3. X-TG, 4. X-G, 5. T-HG,
6. T-G, 7. HXT-G, 8. H-XT, 9. H-X and 10. H-T.

Dielectric Loss angle

Loss angle is an important property of dielectric material. In an ideal dielectric material (loss free material), the phase angle between voltage and current is 90^o. It means that when insulation is subjected to a.c. voltage, all the charging current is capacitive current (I_c). However, due to impurities, certain leakage current flows through the dielectric (I_r) and actual phase angle is slightly less than 90^o by angle δ called loss angle.

Insulation Dissipation Factor

Insulation Dissipation Factor (DF) sometimes referred to as Insulation Power Factor, is a characteristic of the insulating material used in a piece of electrical equipment and is independent of the size and geometry of the insulation. It is a dimensionless ratio expressed in percent, of the resistive current (I_r) flowing through a section of insulation to the capacitive current (I_c) flowing in that insulation.

$$DF = \tan\delta = I_r / I_c$$

Since the resistive current is very small, their ratio should be very small. (Note that ideally the ratio would be zero since ideally $I_r = 0$). Tangent delta ($\tan\delta$) gives an indication of leakage current through the insulation and dielectric loss. It is a good tool to indicate the quality of insulation. A high value of $\tan\delta$ is an indication of presence of contaminants such as moisture, metal oxides, resins, varnishes, dust, carbon particles, etc.

Dissipation factor of new insulating oil as received before transformer filling at 25^oC should be 0.05% maximum and at 100^oC 0.30% maximum. Insulating oil received in new transformer or as tested after final oil filling at 25^oC should be 0.1% maximum and at 100^oC, 1.0% maximum.

Modern transformers insulated with oil/paper materials have dissipation factors of less than 1.0% and often less than 0.5% at 20^oC. The following percentages are to be used in evaluating the results on Askarel and oil-filled (free-breathing and conservator types) transformers and regulators at 20^oC.

Good - Up to 2.0% DF,
Investigate - 2.01 to 4.0% DF,
Bad - 4.01% DF and above

The following percentages are to be used in evaluating the results on oil-filled (sealed and gas blanketed types) transformers at 20^oC.

Good - Up to 1.5% DF,
Investigate - 1.51 to 3.0% DF,
Bad - 3.01% DF and above

For oil filled reactors, test and evaluation as on oil-filled power transformers should be used.

Partial Discharge Test

A partial discharge (PD) can be defined as "localized electrical discharge in insulating material which only partially bridges the insulation between conductors". Partial discharges are in general a sequence of local electrical stress concentrations in the insulation or on the surface of insulation. Generally such discharges appear as pulses

having duration of much less than 1 µs. Partial discharges are often accompanied by emission of sound, light, heat and chemical reactions.

PD Measurement techniques have been developed during 1970's. For transformers designated for system voltages > 72.5 kV, the ACSD is normally performed with PD measurements. The measurement of PD during the whole application of test is a valuable tool for the supplier as well as for the purchaser. Measuring PD during the test may indicate an insulation deficiency before breakdown occurs. The test verifies PD free operation of transformer during operating conditions. PD test may be performed as routine test on all kinds of dry type transformers but especially applicable to transformers having encapsulated windings. It is part of routine tests for power cables. PD measurement is performed in accordance with IEC 60270 and IEC 60076-3.

This is a long duration test intended to check the insulation with regard to voltage under normal operating conditions and temporary over voltages, generally originating from switching operations and faults e.g. load rejection, single-phase faults.

For a power transformer 60 MVA, 132/13.8 kV, YN_0yn_0, 60 Hz, make: HYSOUNG Corporation-HICO, Korea, installed at 132/13.8 kV Al-Naseem, SEC-COA S/S No. 8119, the acceptance value of PD given by the supplier during routine test is lower than 500 pC.

Very Low Frequency (VLF) Hi-Pot Test

In this test a very low frequency test signal is used. Because capacitors act like very high impedances to very low frequencies, the insulation system draws relatively low current and much of it will be the resistive or leakage current. VLF test set identify following significant advantages over AC and DC test sets:

1. Since the insulation draws relatively low current, the VLF test set is much smaller than its 60 Hz counterparts. Also it is comparable in size and weight to a dc hi-pot test set.
2. The VLF signal tends to be less destructive than improperly applied DC test voltages. For this reason, many test personnel have moved away from DC hi-potential testing in favor of the VLF test.

Figure 6 shows the electrical treeing at power frequency. A wide spread electrical tree starting from the needle electrode is obtained. Figure 7 shows the same test set-up, with a VLF applied voltage. The tree almost is reduced to a straight channel. The explanation for the difference is as follows: in case of power frequency the discharge activity is much higher compared to VLF. This means every tree growing leads to a high number of discharges within the tree. Therefore, the material deterioration inside the tree is higher, and therefore the gas pressure inside the tree will strongly increase. Higher pressure inside the tree however leads to better insulation

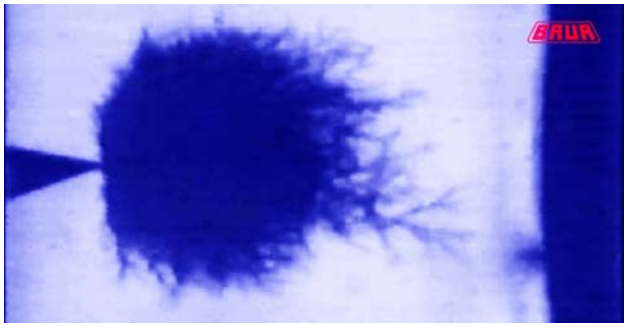

Figure 6: Electrical Treeing On a Cable Sample (Section of a XLPE Cable) with a Defect (Needle Electrode Inside Insulation) at Power Frequency

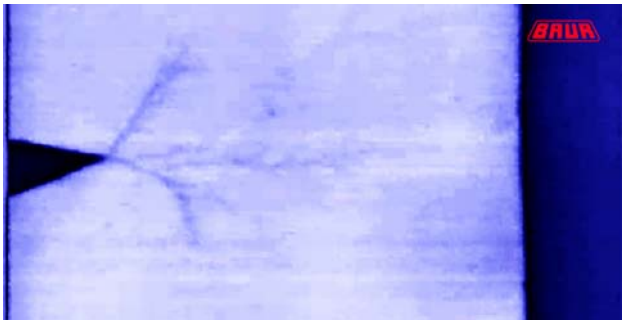

Figure 7: Electrical Treeing On a Cable Sample (Section of a XLPE Cable) With a Defect (Needle Electrode Inside Insulation) at VLF Voltage (0.1 Hz Frequency)

performance (Paschens law), so the tree growth is reduced on this particular tree. Another tree around will grow due to lower electrical insulation level. This leads to wide spread, non well oriented tree growth.

In case of VLF the discharge activity (number of pulses per second) is much lower. Therefore, the tree growth is much more oriented, as it is not a self obstructing mechanism. This results in if there is any defect on the cable, a VLF voltage test will shortly bring this defect to a breakdown. However, if there is no defect, the voltage stress during a VLF test is much lower compared to a power frequency test. This means the VLF test voltage is a very selective (good/bad) and sensitive (breakdown probability within 1 h testing extremely high) tool. The sensitivity in case of XLPE cables is obvious. But also the test performance on PILC and accessories is excellent.

Figure 8 shows the breakdown distribution over the time, DEW Report, 1998 by M. Keller.

The VLF hi-pot sets produce a sinusoidal wave shape independent of capacitive loading and have user selectable frequencies of 0.1 Hz, 0.05 Hz, and 0.02 Hz, with corresponding increasing capacitive loading capability as the test frequency decreases. This capability allows users to choose a lower frequency for longer cable lengths where 0.05 Hz may be used for lengths up to about 20,000 ft, 0.02 Hz for longer lengths and 0.1 Hz for shorter lengths.

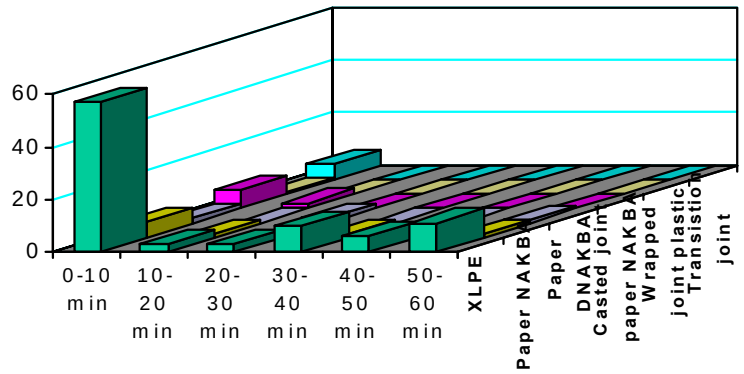

Figure 8: Number of Breakdowns vs. Testing Time for Different Cables and Accessories at VLF Test Voltage

VLF hi-pot sets can be used to proof test circuits after fault repair, to test new services prior to being energized and to test lines that have been out of service for several years and are being used again. Cable circuits can be tested at higher voltages than it is possible with 60 Hz sets and also avoid undesirable effects of dc.

Baur, Austria has designed a VLF test and diagnosis system that combines three test sets into one test unit which can be used for medium voltage cables (see Figure 9).

Figure 9: VLF Test And Diagnosis (DF&PD) System 57 kV_{rms}, 80 kV DC up to 20 µF

Capacitive Canceling Or Resonant Test

This method is normally applied on very high voltage systems of 230 kV and higher. The test set adjusts its own internal inductance to effectively cancel the insulation capacitance and leaves only the resistive (leakage) current to be read.

The last four test systems (Partial Discharge, Insulation Dissipation Factor, VLF and Capacitive Canceling) are relatively specialized systems and may require special training for test personnel. Also, sometimes the results are more complex to analyze.

ANALYSIS OF TEST RESULTS

Experience and judgment have shown that certain values can be expected for equipment in good condition. As an example, oil-filled power transformers should have a dissipation factor of less than 0.5% when new. Over their useful life, that value will increase with the aging of the insulating material but should not exceed 2.0%.

Values over this should be investigated. Ranges of acceptable values are available for many different types of equipment, as a result of years of field-testing experience. However, absolute limits should not be set because of the variety of insulating materials used in electrical equipment.

Comparison of test results with the collected results of tests on similar equipment is another means of evaluating insulation condition. Tests performed on six bushings in a circuit breaker can be compared to each other. Several identical motors tested under similar conditions should give results that are comparable.

Most important is the comparison with the results of previous tests on the same item. These historical values provide a benchmark for subsequent measurements. Trends can be established, and a significant change in test results is one of the first indications that insulation is deteriorating.

Deviation from the normal or previous capacitance value can indicate moisture contamination in insulation or possible shorted sections of insulation. Capacitance measurements are especially important for insulating systems with several capacitor sections in series, such as a bushing with capacitance tape or a coupling capacitor. Changes in dissipation factor are caused by normal aging, moisture, contamination or chemical deterioration.

CONCLUSION

AC insulation tests discussed above cover the tests those are carried out during routine tests, pre-commissioning tests, preventive maintenance and corrective maintenance. Dielectric tests like lightning impulse, chopped impulse and switching impulse are not discussed because these are DC insulation tests. Routine tests are conducted at manufacturer's premises as per recommendations of standards IEC, BS, GOST or ANSI. These tests reveal the defects in the materials and construction. Power frequency voltage withstand, separate source voltage withstand, induced over voltage, partial discharge, C & DF and dielectric test on auxiliary and control circuits discussed above are part of factory routine tests for various apparatus as per specific requirement and standards. Partial discharge test is part of routine test for power transformers with Um > 72.5 kV, dry type transformers, epoxy cast resin CTs and VTs and power cables. It is special test for oil immersed transformer with Um ≤ 72.5 kV. The results of routine tests confirm the quality of product. Pre-commissioning tests are conducted on electrical apparatus (transformer, circuit breaker, switchboard etc.) after installation at site to verify that there are no transit damages and installation is satisfactory. Power frequency voltage withstand test at 80% of rated power frequency voltage as per IEC and at 75% of (2 x equipment maximum voltage + 1kV) as per ANSI are part of pre-commissioning tests.

C & DF test is performed during pre-commissioning and routine maintenance of power transformer. The most important criteria for diagnosis are the comparison with previous test record on the same apparatus or other similar apparatus. The step-up or induce voltage test can detect inter-turn insulation failure of transformer. AC insulation field tests are not sufficient for knowing the overall status of transformer insulation. AC insulation tests supplemented with non-destructive DC insulation tests like insulation resistance, polarization index, recovery voltage and time constant allow us to predict an abnormal aging in paper / oil insulation and contamination of the insulation. A condition based maintenance system for transformers will include AC & DC insulation tests, and some additional tests like turn ratio, winding resistance and measurement of short circuit impedance.

VLF, DF and PD tests are powerful diagnostic tools for condition based maintenance of power cables. VLF test is more selective and sensitive to defects compared to testing at power frequency. DF diagnosis enables a judgement of the insulation situation of the whole cable insulation, using criteria to judge good and bad cables. PD diagnosis gives a tool to detect and locate single defects, mostly located in accessories, prior to breakdown.

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CHARTERED UNIVERSITIES / DEGREE AWARDING INSTITUTES
IN PRIVATE SECTOR

	CHARTERED UNIVERSITY / DEGREE AWARDING INSTITUTE	ESTABLISHED ON
1.	Agha Khan University, Karachi (http://www.akuweb.com)	2nd March 1983
2.	Al-Khair University, Mirpur, Azad Kashmir	11th July 1994
3.	Baqai Medical University, Karachi	26th May 1996
4.	Beaconhouse National University, Lahore (http://www.bnu.edu.pk)	2nd July 2005
5.	CECOS University of Info. Technology and Emerging Sciences, Peshawar (http://www.cecos.com)	30th August 2001
6.	City University of Science & Information Technology, Peshawar (http://www.cityuniversity.edu.pk)	30th August 2001
7.	College of Buisness Administration & Economics (NCBA&E) Lahore (http://www.ncbae.edu.pk)	10th April 2002
8.	Dadabhoy Institute of Higher Education, Karachi	12th January 2004
9.	Forman Christian College, Lahore	12th October 2004
10.	Foundation University, Islamabad	25th October 2002
11.	Gandhara University, Peshawar (http://www.gandhara.edu.pk)	23rd November 2002
12.	Ghulam Ishaq Khan Institute of Engineering Sci. & Technology, Swabi (http://www.giki.edu.pk)	18th July 1994
13.	Gift University, Gujranwala (http://www.gift.edu.pk)	10th June 2004
14.	Greenwich University, Karachi (http://www.greenwichuniversity.edu.pk)	3rd February 1998
15.	Hajvery University, Lahore (http://www.hajvery.edu.pk)	2nd October 2002
16.	Hamdard University, Karachi (http://www.hamdard.edu.pk)	22nd February 1992
17.	Imperial College of Business Studies, Lahore (http://www.imperial.edu.pk)	10th April 2002
18.	Indus Institute of Higher Education, Karachi	20th October 2004
19.	Indus Valley School of Art and Architecture, Karachi (http://www.indusvalley.edu.pk)	27th July 1994
20.	Institute of Business & Technology BIZTEK, Karachi (http://www.biztek.edu.pk)	12th January 2004
21.	Institute of Business Management, Karachi (http://www.cbm.edu.pk)	27th April 1998
22.	Institute of Management Sciences, Lahore (http://www.pakaims.edu.pk)	10th April 2002
23.	Iqra University, Karachi (http://www.iqra.edu.pk)	21st June 2000
24.	Iqra University, Quetta (http://www.iqra.edu.pk)	2nd November 2002
25.	Isra University, Hyderabad (http://www.isra.edu.pk)	27th September 1997
26.	Jinnah University for Women, Karachi (http://www.juw.edu.pk)	2nd June 1998
27.	Karachi Institute of Economics & Technology, Karachi	24th May 2000
28.	KASB (Khadim Ali Shah Bukhari) Institute of Technology, Karachi (http://www.kasbit.edu.pk)	28th June 2001
29.	Kinnaird College for Women, Lahore	25th October 2002
30.	Lahore School of Economics, Lahore (http://www.lse.edu.pk)	8th January 1997
31.	Lahore University of Management Sciences (LUMS), Lahore (http://www.lums.edu.pk)	31st March 1985
32.	Minhaj University, Lahore	15th October 2005
33.	Mohammad Ali Jinnah University, Karachi	1st July 1998
34.	Mohi-ud-Din Islamic University, Nerian Sharif, Azad Kashmir (http://www.miu.edu.pk)	18th January 2000
35.	National Textile University, Faisalabad	15th November 2002
36.	National University of Computer and Emerging Sciences, Islamabad (http://www.nu.edu.pk)	1st July 2000
37.	Newports Institute of Communications and Economics, Karachi (http://www.newports.edu.pk)	30th May 2002
38.	Northern University, Nowshera Cantonment	2nd November 2002
39.	Preston Institute of Management Sciences and Technology, Karachi (http://pimsat-khi.edu.pk)	31st July 2001
40.	Preston University, Karachi	18th February 2004
41.	Preston University, Kohat	23rd November 2002
42.	Qurtaba University of Science & Information Technology, D. I. Khan (http://www.qurtuba.edu.pk)	30th August 2001
43.	Riphah International University, Islamabad (http://www.riu.edu.pk)	16th October 2002
44.	Sarhad University of Science & Information Technology, Peshawar (http://www.suit.edu.pk)	30th August 2001
45.	Shaheed Zulfikar Ali Bhutto Institute of Science & Technology (SZABIST), Karachi (http://www.szabist.edu.pk)	25th October 1995
46.	Sir Syed University of Engineering. & Technology, Karachi (http://www.ssuet.edu.pk)	25th October 1995
47.	Textile Institute of Pakistan, Karachi (http://www.tip.edu.pk)	21st April 2001
48.	The Superior College, Lahore (http://www.superior.edu.pk)	16th June 2004
49.	The University of Management & Technology, Lahore (http://www.umt.edu.pk/index.htm)	16th June 2004
50.	University of Central Punjab, Lahore (http://www.ucp.edu.pk)	10th April 2002
51.	University of East, Hyderabad (http://www.universityofeast.com)	28th July 2004
52.	University of Faisalabad, Faisalabad (http://www.tuf.edu.pk)	2nd October 2002
53.	University of Lahore, Thokar Niaz Baig, Lahore	2nd October 2002
54.	University of South Asia, Lahore (http://www.usa.edu.pk)	9th July 2005
55.	Zia-ud-Din Medical University, Karachi	8th October 1995

37 Chartered Universities and 18 Degree Awarding Institutes in Private Sector **Total 55**

RFID: TECHNOLOGY, APPLICATIONS AND PRIVACY CONCERNS

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ABSTRACT

Radio Frequency Identification (RFID) devices are in limelight for the last few years. These smart devices are evolving as a major technology enabler for tracking goods and assets around the world. These are nowadays embedded in the consumer items and may soon become pervasive in our daily lives. This paper provides an introduction to the technology and discuses the RFID system components and their functional interactions. It also presents a summary of standards and regulations, and identifies the capabilities and limitations of the current technology. The paper also provides an overview of RFID application in supply chain industry and in other commercial sectors. At the end, the paper discusses the security and privacy issues surrounding the use of this technology.

INTRODUCTION

Radio Frequency Identification (RFID) is a technology that identifies objects using radio frequency waves. The technology can be used to identify, track and store information about a wide variety of objects. In its most basic form, RFID requires two components – a **tag** (or transponder), which is attached to an object, and a **reader** (or transceiver), which creates a radio frequency field that detects radio waves. The tag consists of a microchip that contains identifying information about the object and an antenna to communicate that information via radio waves. When a tag passes through a radio frequency field generated by a compatible reader, the tag reflects back to the reader the identifying information about the object, thus identifying that object.

RFID is not a new technology – it has actually been around since World War II, when it was used by Britain to distinguish allied and enemy aircrafts. During the late 1960s and early 1970s, companies began developing electronic article surveillance equipment to protect inventory items such as clothing in departmental stores and books in libraries. Throughout the ensuing years, there have been many notable uses of RFID technology in the commercial and military arena. One museum in Rotterdam uses RFID to guard its priceless paintings, and U.S. Department of Defense (DoD) uses RFID technology to track major shipments of all its ordnance and medical supplies around the world. In addition, scores of livestock have been tagged with RFID in order to track them in the event of a disease outbreak. One of the most visible uses of RFID in today's society is automated toll-collection on turnpikes and bridges, where the tollbooths equipped with readers identify the car and then charge the toll to the correct account as the car passes through the booth.

RFID SYSTEM COMPONENTS

A RFID system is composed of four fundamental components:

1. RFID Tag (or transponder)
2. RFID Reader (or transceiver)
3. Reader Antenna
4. Host System

A typical RFID system is shown in Figure 1. The tag is programmed with information that uniquely identifies the

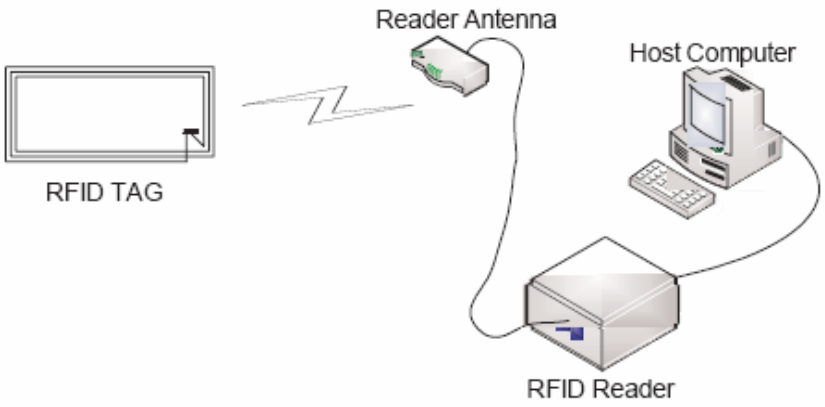

Figure 1: RFID System Components

object. It is activated when it passes through a radio frequency field generated by an antenna and the reader. In response, the tag reflects back the programmed information about the object. The antenna detects that response and sends it to the receiver. The reader then decodes this information and forwards it to the host computer, where this information is used in some software application. The RFID system components are discussed next.

RFID Tag

A RFID tag, or transponder, is a device that can store and transmit data to a reader (transceiver) in a contact-less manner using radio waves. It contains a silicon microchip, smaller than a grain of sand, and a small coiled antenna encapsulated in flexible plastic or durable paper. A typical tag is shown in Figure 2.

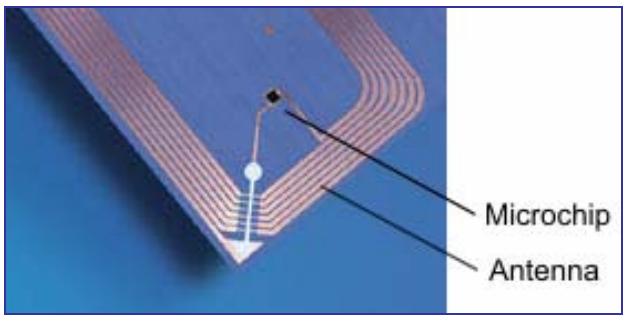

Figure 2: A Typical Tag

Figure 3: Various Types of Tags

The tags can be located inside or on the surface of the product, item, or packing material. The size and shape of the tag antenna typically determines the limits of the dimensions of the entire tag. Depending on antenna, the tag's size and shape can vary tremendously – it can be a tiny millimeter-square chip, a thin credit card shape, a flat label that can be stuck onto inventory items, a token or a coin, or even a screw to be inserted into a crate. A few of these tags are shown in Figure 3.

Tag Types

There are three main types of RFID tags:

- Active
- Passive
- Semi-passive (also known as semi-active)

The tags differ depending on the power source and the tag's functionality. The following subsections discuss these RFID tags in detail:

Active Tags

An active tag has its own battery power to contact the reader. Power from the battery is used to run the microchip's circuitry and to broadcast a signal to a reader. The onboard power source enables the tag to perform specialized tasks and broadcast signals out at great range with better accuracy. Some of the more powerful active tags can communicate up to several kilometers. These are much larger and can contain microprocessors, sensors, large memory and input/output ports for performing specialized tasks. These are usually capable of operating over a temperature range of -50°C to +70°C. Due to an onboard battery, these tags have a finite lifetime – usually 3 to 5 years of transmission time.

The active tags are relatively expensive, therefore these are used for high-value goods that need to be tracked at ranges of 25 meter or more. Despite higher cost, active tags have proven a significant return on investment (ROI) for many applications. One of the more common uses for active tags is for tracking high-value objects over long ranges such as tagging and tracking of military supplies shipped around the world. However, active tags are also used in many other commercial applications where environmental conditions and application requirements demand more robust tag and reader communication. Certain types of active tags used in the transport and shipping industries can integrate with Global Positioning System (GPS), cellular communication network, or satellite system to give exact whereabouts and provide constant communication back to a tracking program.

Table 1: Comparison of Active, Semi-passive and Passive Tags

TAG	ADVANTAGES	DISADVANTAGES
Active	• Long range (greater than 100 meters) • Can be used to manage other devices like sensors • Large read/write data storage with sophisticated data search and access capabilities • Self-activated in presence of a reader	• Higher cost • Impossible to determine battery condition • Larger size • Limited operational life
Semi-Passive	• Long range (up to 100 meter) • Can be used to manage other devices like sensors • Large read/write data storage with reasonable data search and access capabilities • Better operational life compare to active tags	• Higher cost • Impossible to determine battery condition • Larger size than passive tags
Passive	• Long operational life • Wider range of form factors • Smaller size • Lowest cost • Tags are more mechanically flexible	• Shorter communication range (3 to 10m) • Strictly controlled by local regulations • Small data storage (e.g. 128 bytes) • Needs higher powered reader • Mostly read-only

Passive Tags

A passive tag does not have its own power source; rather, it drives power from the electromagnetic field created by the reader's radio signal to energize its microchip and to respond the reader (backscattering) with the information contained in its memory. These tags have favorable form factors and are relatively inexpensive, partly because these require no battery power. These tags have an almost indefinite lifetime and are generally resistant to harsh environmental conditions.

Passive tags are constrained in their capacity to store data and the ability to perform well in noisy electromagnetic environments. The read range of these tags also depends on many factors: the frequency of operation, the power of the reader, interference from metal objects or other radio frequency devices. These factors typically constrain the passive tag operation to 3 to 10 meters. However, depending on the vendor and frequency of operation, the range may be as short as a few centimeters.

Many solutions are currently in place that employs passive tag technology, such as animal tracking, asset management, industrial automation, electronic article surveillance, and access control applications. Due to their lowest cost, passive tags have the most potential; hence, these are the primary focus throughout this paper.

Semi-Passive

A semi-passive or semi-active tag has its own battery power to operate the tags microchip and perform specialized tasks. However, it still drives power from the electromagnetic field created by the reader's radio signal to wake-up or activate, and to transmit the information contained in its memory. This allows the semi-passive tag to function with much lower signal power levels, resulting in distances of up to 100 meters. Distance is limited mainly due to the fact that tag does not have an integrated transmitter, and is still obliged to use the reader's radio signal to communicate back to the reader.

The semi-passive tags are usually larger and more expensive than passive tags and are used to track high value goods. Because no time is needed for energizing a semi-passive tag, its data can also be read while the tagged object is moving at a high speed. Batteries used in these types of tags typically last 5 to 10 years because power is only consumed when the tag is activated and is in the reader's field.

A comparison of Active, Passive and Semi-Passive tags is shown in Table 1.

Tag Memory

Memory Size

Memory is one of the most important components of a tag and its proper use can greatly enhance the functionality of an application. The tag memory can range from 16 bytes to 256 Kbytes. However, because of power limitations, passive tags typically provide only a small amount of data storage, in the order of 128 bytes or less, with no search capability or other data manipulation features. Active tags have the flexibility to remain powered for access and search of larger data, as well as the ability to transmit longer data packets. Active tags are in common use with 128 Kbytes of dynamically searchable data storage.

Memory Types

Depending on the tag type and design, the tag memory can be read only (RO), write once read many (WORM) or read/write (RW).

Read Only (RO): A read only (RO) tag can be programmed or written just once in its lifetime. The data on these tags (usually a unique identification code) is burned permanently at the factory during a manufacturing stage. Once this is done, the data cannot be rewritten. This type of tag is the most common and the cheapest tag, and is good for small applications only. It is mostly used in price sensitive mass applications with low local information requirements.

Write Once, Read Many (WORM): A write once, read many (WORM) tag can be programmed or written only once. The data on these tags is generally written by a tag user at the time when the tag needs to be created. In practice, however, the data on some WORM tags can be overwritten several times. The WORM tag offers a good price-to-performance ratio with reasonable data security, and is the most prevalent type of tag used in business today.

Read/Write (RW): A read/write (RW) tag can be reprogrammed or rewritten a large number of times. Typically, this number varies between 10,000 and 100,000. This type of tag memory offers a tremendous advantage because the data on the tags can be written or changed dynamically, either by the readers or by the tag itself (in case of active tags). The RW tags are the most expensive tags and, therefore, are generally used to track high-priced, valuable items. These tags are also used in some specialized applications to record temperature, time or other physical data.

RFID Reader

An RFID reader, also called transceiver or interrogator, is a handheld or stationary (fixed-mount) device that captures and processes the tag data. Although some readers can also write data onto a tag, the device is still referred to as a reader. A typical hand-held RFID reader is shown in Figure 4.

Communication of data between a tag and a reader is by wireless communication. Two methods distinguish and categorize RFID systems, one is based upon close proximity of electromagnetic or inductive coupling and other one is based upon electromagnetic backscatter or propagation coupling. Coupling is via antenna structures forming an integral feature in both tag and a reader.

A reader performs a variety of functions including activating tags by sending querying signals, supplying power to passive tags, decoding the data received from the tag, and encoding the data going to the tag.

In the case of passive and semi-passive tags, the reader provides the energy required to activate or energize the tag in the reader's electromagnetic field. The reach of this field is generally determined by the radio frequency and the output power of the reader.

Figure 4: RFID Hand-Held Reader

The most common task that a reader performs is to read the data stored on the tag. In the case of passive and semi-passive tags, the reader sends periodic radio signals at a given frequency to inquire about the presence of any tag in the vicinity. On receiving a reader's radio signal, a tag sends the data stored in its memory back to the reader. The reader then decodes this data and forwards it to the host computer. Active tags periodically transmit a signal, much like a light house beacon, so that the data may be captured by a reader.

In the case of read/write (RW) tags, a reader can perform a dual function by also writing data onto a tag. For this, the reader first encodes the data and then transmits it to tag by sending radio signals.

Multiple tags can also be read within a single field. However, the circuitry needs time to identify each individual tag's identity and to read the data from that tag. Thus, reading of multiple tags is not instantaneous; and depending on the number of tags within the field, the identification and reading process can take a significant amount of time.

Reader Antennas

The reader antennas act as conduits for data communication between the tag and the reader. They send radio signals into the air to activate a tag, listen for an echo (backscatter) from the tag, read the data transmitted by a tag, and, in some cases, write data onto a tag.

A reader antenna is usually a separate device that is physically attached to a reader, at one of its antenna ports, by means of a shielded coaxial cable. In certain cases, such as handheld readers, the antenna is mounted directly on the reader. A reader antenna is also called the reader's coupling element because it creates an electromagnetic field to couple with the tag. A single reader can typically support up to four antennas.

Reader antennas function continuously or on-demand. Continuously active antennas are used when tagged items are present on a regular basis or when multiple tags are passing through the antenna detection field. On the other hand, the antennas can be activated on-demand by using some type of sensor.

Antenna design and placement plays a significant factor in determining the coverage zone, range and accuracy of communication. These come in a variety of shapes and sizes, and can cover an area as small as few centimeters to as large as 100 meters, depending on the output power and the frequency. This diversity in shape, size and range allows antenna placement in a wide variety of locations.

Host System

The host system provides a means of processing and storing the data received from a receiver. It consists of computer hardware, operating system, data repository and the software applications. The host computer receives data from readers and uses it in applications such as enterprise resource planning (ERP), warehouse management system, shipping, logistics or identification management systems. The hardware characteristics of a host computer are generally dependent on the type of software applications running on the computer.

STANDARDS AND REGULATIONS

One of the most important aspects of RFID technology is the associated standards and regulations. They help to serve consumers in many ways – they ensure that different products don't interfere with each other's functions, they enable interoperability between different manufacturer's readers and tags, and they also guarantee interoperability between applications.

Standards

The history of RFID standards over the last decade has unfortunately been far from ideal, leading to many variations and confusion. However, the situation started changing in recent years. Several bodies are currently progressing with specific standards for RFID to ensure that performance and interoperability metrics are met. There are, however, two major organizations into the business – International Organization for Standardization (ISO) and Electronic Product Code Global (EPCglobal). The standards proposed by both of these organizations are reviewed here.

ISO has developed several RFID standards for automatic identification and item management. These standards cover the air interface protocol, tag and reader performance test methods, and unique identification of tag and registration authority. The major ISO protocols are listed below in Table 2.

Table 2: Information Technology AIDC Techniques – RFID for Item Management

STANDARD	DESCRIPTION
ISO 18000-1	Generic Parameters for Air Interface Communications for globally accepted frequencies
ISO 18000-2	Parameters for Air Interface Communications below 135 kHz
ISO 18000-3	Parameters for Air Interface Communications at 13.56 MHz
ISO 18000-4	Parameters for Air Interface Communications at 2.45 GHz
ISO 18000-5	Parameters for Air Interface Communications at 5.8 GHz
ISO 18000-6	Parameters for Air Interface Communications at 860MHz to 930 MHz
ISO 18000-7	Parameters for Air Interface Communications at 433.92 MHz
ISO 18046	RFID tag and RFID reader performance test methods
ISO 18047	RFID device conformance test methods
ISO 15963	Unique Identification of RF Tag and Registration Authority to Manage the Uniqueness

The EPCglobal work is to define a networked RFID system architecture by specifying standards, in order to guarantee full-scale global interoperability between devices from different technology vendors. In the EPCglobal model these systems involve a number of components including the following items:

- Electronic Product Code (EPC)
- Electronic Tags
- Object Naming Service (ONS)
- Air Interfaces

Working in coordination, these components provide the ability to capture and share information in the EPCglobal Network.

Electronic Product Code (EPC) is a numbering scheme that allows assignment of a unique identifier to any physical object, thus allowing the object to be uniquely identified. It was developed at MIT's Auto-ID Center in 2000 and is now managed by EPCglobal. The EPC can be regarded as the next generation Universal Product Code (UPC), which is being used on most products today.

EPC codes are stored on EPC tags that are read by EPC readers. The format of EPC Class I tag, that allows the unique identification of objects, is shown below.

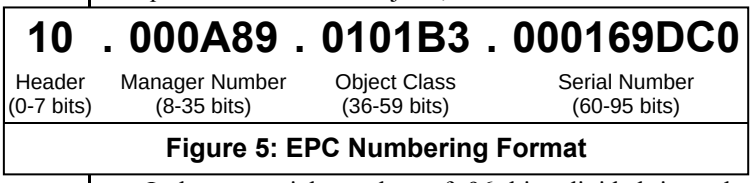

Figure 5: EPC Numbering Format

It has a serial number of 96 bits divided into the following fields:

- **Header:** Identifies the EPC's version number
- **Manager Number:** Identifies the enterprise using the EPC number
- **Object Class:** Refers to the class or category of a product
- **Serial Number:** Identifies a unique instance of the item being tagged

This 96-bit EPC specification provides unique identifiers for 268 million companies. Each company can have 16 million object classes, with 68 billion serial numbers in each class.

An **Electronic Tag** uniquely identifies an object, to which it is attached, via a unique EPC number. They are usually categorized by their capability to read and write data. EPCglobal has defined five classes of tags, which are outlined in Table 3:

Table 3: EPCglobal Tag Classes

TAG CLASS	DESCRIPTION
CLASS 0	Read Only (RO) – Pre-programmed by the manufacturer
CLASS 1	Write Once Read Many (WORM) – One time programmable by manufacturer or by the user
CLASS 2	Read Write (WR) – User may read or write tag's memory
CLASS 3	Read Write (WR) with onboard sensors – Tag records data from its onboard sensors
CLASS 4	Read Write (WR) with integrated transmitters – Tag communicate with other tags and devices without the presence of a reader

Object Naming Service (ONS) is an application running on a host system that collects the EPC numbers from reader and informs the host system where to find information about the object. Typically this information may reside on the host computer, host network, or on other computer systems accessed via the Internet.

The RFID **Air Interface** specifies the radio communication protocol between tags and the readers.

Regulations and Frequency Allocation

The frequency of an RFID system defines the relationship between the tag and the reader, and impacts a number of factors, including:

- Data transfer rate (higher the frequency the higher the data rate)
- Transmission range (higher the frequency the further the range and higher reader power needed)
- Size and cost of tag construction (lower the frequency the higher the cost of antenna for passive tags)

The allocations of frequency band and reader emission power are subject to regulations imposed by local governments to prevent interference with other equipment. RFID tags and readers fall under the category of short range devices (SRD) and, therefore, these do not normally require a license. However, the products themselves are governed by the regulations which vary from country to country.

RFID systems can be built to operate primarily in four frequency bands:

1. < 135 KHz Low Frequency (LF)
2. 13.56 MHz High Frequency (HF)
3. 4.33 MHz and 860-930 MHz Ultra High Frequency (UHF)
4. 2.45 GHz and 5.8 GHz Microwave Frequency

Lower-frequency RFID systems provide shorter read range (< 0.5 meter) and slower data transfer, but they use

Table 4: Four Main Frequency Bands, Along with the Key Characteristics and Applications

FREQUENCY	KEY CHARACTERISTICS	TYPICAL APPLICATIONS
Low Frequency (LF) **< 135 KHz**	• Passive tag read range ~ 0.5 meter • Tag power source – Passive • In use since 1980s and widely deployed • Works best around metal and liquid • Lowest data transfer rate • Larger Antennas resulting in higher cost tags	• Animal identification • Industrial automation • Access control • Inventory control • Vehicle immobilizer • Product authentication
High Frequency (HF) **13.56 MHz**	• Passive tag read range ~ 1 meter • Tag power source – Mainly Passive • In use since mid 1990s and widely deployed • Common worldwide standards • Longer read range than LF tags • Lower tag costs than LF tags • Poor performance around metal • Widest application scope.	• Payment and loyalty cards (Smart Cards) • Access control • Anti-counterfeiting • Item level tracking such as books, luggage, garments, etc. • People identification and monitoring
Ultrahigh Frequency (UHF) **433 MHz (active) and 860 MHz to 930 MHz (passive)**	• Passive tag read range ~ 3 to 10 meter • Tag power source – Active and Passive • In use since late 1990s • Longer read range than HF tags • Very long ranges for active 433 MHz systems • Gaining momentum due to worldwide retail supply chain mandates • Potential to offer lowest cost tags • Incompatibility issues related to regional regulations • Susceptible to interference from liquid and metal • Good for reading multiple tags at long range	• Supply chain and logistics such as inventory control, warehouse management and asset tracking • Transport monitoring • Baggage handling • Electronic toll collection.
Microwave **2.45 GHz and 5.8 GHz**	• Passive tag read range ~ 1 meter • Tag power source – Active and Passive • In use for several decades • Fastest data transfer rates • Common in active and semi-active modes • Read range is similar to UHF • Poor performance around liquid and metal	• Access Control • Electronic toll collection • Industrial automation • Transport monitoring • Vehicle identification • Airline baggage tracking

less power than the higher frequency systems. These systems have the strongest ability to read tags on objects with high water or metal content compared to any of the higher frequencies.

Higher frequency RFID systems typically offer greater read range and higher data transfer, but they use more power than low frequency systems. These systems have limited ability to read tags on objects with or surrounded by high water or metal content.

Microwave RFID systems have a limited read range of up to 1 meter but they offer the fastest data transfer rates. Additionally, these systems are not able to penetrate objects with high water or metal content and they are the most expensive systems.

Currently, only 13.56 MHz (HF) band is globally accepted as an ISO standard. This discontinuity has resulted in the International Telecommunications Union (ITU) dividing the world into three regulatory regions. These regions are as follows:

Region 1: Europe, Middle East and Africa
Region 2: North and South America
Region 3: Asia, Australia and Far East countries

Each country manages its frequency allocations within the guidelines set out by these regions.

Table 4 summarizes the four main frequency bands, along with the typical system characteristics and examples of major areas of application.

ADVANTAGES AND DISADVANTAGES

The most important advantages and disadvantages of RFID technology are listed below:

Advantages

- **No physical contact:** Tag can be read without any physical contact between the tag and the reader
- **Absence of line-of-sight:** Line of sight is not required for a reader to read a tag
- **Re-programmable:** Data of a read/write (RW) tag can be rewritten dynamically
- **Variety of read ranges:** Tag can have a read range from few centimeter to more than 100 meter
- **Wide data-capacity range:** Tag can store from a few bytes of data to a large amount of data
- **Wide and versatile tag format:** Available in different shapes and sizes
- **Multiple tag reads:** Multiple tags can be read within a short period of time
- **Rugged:** Can sustain rough operational environment conditions to a fair extent
- **Penetrates in most objects:** The radio signal penetrates dirt, moisture, and most nonmetallic objects
- **Secure:** Tag can be hidden, is difficult to counterfeit, and can trigger security alarms if removed
- **Monitors shelf life:** RFID systems can identify the expired or outlasted drugs, food and other perishable products
- **Suppress theft and black market:** Unique tag identity can assist in recovering lost or stolen items

Disadvantages

- **Relatively expensive:** Relatively high cost of tags makes it expensive for low-value items
- **Higher capital cost:** Implementation of RFID infrastructure requires higher capital cost
- **Environmental constraints apply:** External influences such as moisture, presence of metalwork and surrounding building structure can constrain RFID signal
- **Lack of standards:** Currently there are not internationally agreed frequencies for RFID operation except 13.56 MHz, which is primarily used for smart cards
- **Limited read range:** Tags can be read only within a limited range.

APPLICATIONS

The applications for RFID have been identified in virtually every sector of industry, commerce and services where data is to be collected. These range from remote keyless entry for automobiles to object tracking, highway toll collection, supply-chain management, security, and smart payment cards. New applications are constantly being developed and more will be discovered as the industry adopts the technology on a wider scale.

Leading Areas of Application

The following are the examples of some leading areas of applications where the RFID technology has demonstrated significant benefits:

Supply Chains

The unique capabilities of RFID over traditional bar coding make it an exciting option to complement data

collection and product identification in the supply chain. RFID will allow manufacturers, retailers, and suppliers to efficiently collect, manage, distribute, and store information on inventory, business processes, and security controls. The wide adoption of RFID across the supply chain will bring significant benefits leading to reduced operational costs and hence increased profits.

At the heart of the RFID based technology drive to improve supply chain efficiency is the Electronic Product Code (EPC). The EPC, discussed above, is being promoted as a single, open worldwide RFID standard. In addition to being an identification code, it will also serve as pointers to database entries, thereby allowing the compilation of extensive automated histories for individual products. All parts of the supply chain including manufactures, distributors and retailers will be able to have instant access to this information – this will give an exact picture of the product to all the players.

Improved supply-chain management is the initial goal of major RFID deployments in the next few years. Therefore, the adoption is likely to happen first at the palette and crate level. As technology advances and the tag costs reduce, we can expect to see tags on consumer goods as well. Currently, the EPC standard is the focus of Wal-Mart and the Department of Defense (DoD) in the United States. This positions EPC as the leader for large supply-chain implementations.

Vehicle Identification and Registration

A vehicle identification and registration system, as illustrated in Figure 6, identifies the vehicle and validates its identity, status, and the authenticity. It also provides an equitable means to enforce vehicle registration law. By the virtue of RFID, these systems have shown remarkable and significant results.

In Pakistan, National Database and Registration Authority (NADRA) is working on a project to implement a Vehicles Inspection and Monitoring System (VIMS) in Islamabad and Karachi. This system will allow law enforcement authorities to track and monitor the vehicles; it will enable the government agencies to automatically detect and screen vehicles for compliance with vehicle regulations; and it will serve as effective security deterrence against car snatching and using it in criminal activities. Under the project, it would be mandatory for every vehicle to get an RFID tag. For this NADRA would setup many locations for issuing and fixing these tags to vehicles. In addition, it will establish check posts and mobile units at all police checkpoints, major bridges and entry/exit points of the towns. These check posts and mobile units would be equipped with RFID readers and antennas to read details of every vehicle. The VIMS would link NADRA's existing network and data warehouse infrastructure.

Figure 6: Vehicle Identification and Registration System

Access Control

The most important use of RFID systems is in access control and other security application. NADRA in Pakistan is using this technology in Machine Readable Passport (MRP) which is first of its kind in the world, in terms of features and components it encompasses. This passport (shown in Figure 7) uses a 4 KB RFID tag which includes encrypted data of the applicant, and Facial Recognition and Fingerprint Identification technologies. The passport is compliant with International Civil Aviation Organization (ICAO) standards on e-passports.

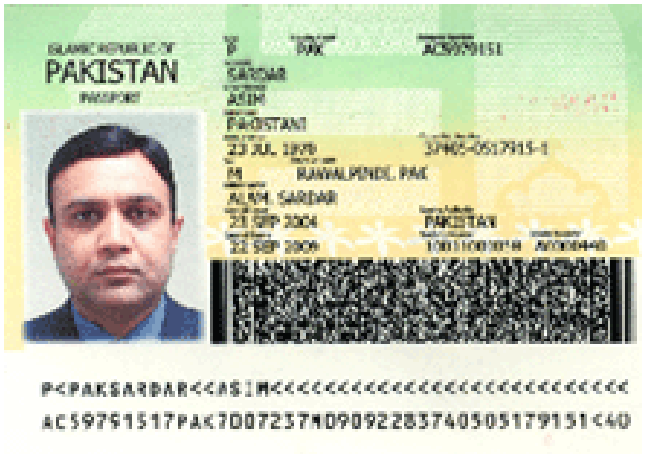

Figure 7: RFID-based Machine Readable Passport

Starting in 2006, the U.S. Department of State will also begin issuing passports with 64 KB RFID tags that will contain the personal data and digitized photograph of the passport holder, as well as encrypted digital signatures to prevent tampering or forgery.

Toll Collection

Conventional toll collection methods require the driver to deposit coins, tickets, or tokens at toll plazas. This reduces the highway's traffic throughput, because the number of vehicles per hour that can be processed at toll plazas is limited. To overcome this problem, highway

authorities in many metropolitan areas now let travelers pay tolls using RFID tags linked to debit accounts. E-ZPass is a good example of such a system, first used widely in New York. With E-ZPass, account information on RFID tag installed on vehicle is read by a receiving antenna as vehicles pass through a toll plaza with speed up to 160 km per hour. The toll is then deducted electronically from the vehicle owner's prepaid toll account.

Libraries

RFID system in libraries offers excellent user friendly environment with self-service desk for check-out and check-in. The libraries in Singapore have aggressively implemented this technology and all 9 million books, videos and DVDs in these libraries are now embedded with antitheft chips. Over 130 libraries in North America are also using RFID technology and hundreds others are in a process of implementing it. The San Francisco Public Library, which circulates about 6 million items annually, projects spending $2.8 million on RFID over the next few years.

Payment Systems

The payment systems operate as part of cash collection and fast payment systems. These systems allow customers to pay the expenses by passing a credit-card like tokens, embedded with their ID code, over an ID reader. The system then automatically debits the value from the customer's account. To make fraud more difficult, some systems combine the code with a simple challenge–response protocol.

Automobile Immobilizers

In automobile immobilizers, the car key incorporates an RFID tag that the steering column authenticates, thereby enabling vehicle operation.

Other Areas of Application

Even though RFID applications are still at the early stages of deployment, many valuable use cases have been identified that span industries. The following list shows some of these industries and the specific use cases identified in each sector:

Security

- Asset protection and tracking
- Electronic monitoring of offenders at home
- Museum, art gallery, library item identification, logging, security and control
- Police investigation evidence tagging and location
- Controlled access of personnel to secure or hazardous locations
- Controlled access to vehicles, parking areas and fuel facilities

Transportation and Logistics

- Asset management, tracking and maintenance
- Supplies and materials management
- Shipment route tracing and identification of package contents
- Courier shipments and postal parcel tracking
- Airline baggage handling
- Automated customs

Manufacturing and Processing

- Time and attendance
- Manufacturing inventory accounting and control
- Capital goods service record logging and recall
- Parts tracking
- Identification of product variants and process control
- Container and tool management

Healthcare

- Monitoring blood banks
- Monitoring medication routes from medicine cabinet to patient
- Drug recall (product pedigree)
- Identifying counterfeit or falsely-labeled medications
- Identifying expired or near-to-expire medications
- Hospital patient identification, treatment and medication recording

Retail

- Product tracking and tracing
- Streamlined shipping and receiving
- Automated invoice reconciliation
- Shrinkage reduction
- Improved demand planning

Animal Tagging

- Mad Cow Disease/Bird Flu – cow/bird pedigree and herd/flock history
- Animal husbandry – for identification in support of individualized feeding programs

SECURITY AND PRIVACY CONCERNS

Despite the technology's current widespread use and significant future potential, concern has arisen about the security of data stored in tags, and the possibility of misusing RFID technology for tracking and profiling individual people. These issues are discussed in the following sections:

Security

Since many organizations have already turned to use RFID for many large-scale applications, it is vital to ensure the security of these systems. The main goal of a security system designed to protect data stored in tags is to prevent the unauthorized persons from being able to read, modify, corrupt, erase, or duplicate the data contents. The main threats to data stored in tags arise from the possibility of snooping via radio; which can be prevented by a combination of three features as follows:

1. Authorization – tag requiring password from reader
2. Authentication – reader recognizing the tag with its unique signature
3. Encryption of data transmitted between a tag and the reader

However, designing such a system is extremely challenging because, generally, a passive tag's processing power and memory is below the requirements for embedding cryptographic algorithms.

In an RFID system, the security of data not only involves the tags and readers but also how data is stored in a host or transferred from a host to the medium (or vice versa). Therefore, the protection of complete RFID systems through the proper authentication, encryption, and database security is critical to any RFID implementation plan.

Privacy Concerns

RFID tags can be read at a distance without a person's knowledge. As a result, tags placed in consumer items for one purpose might be covertly used to track people as they move through the world. This is especially true of RFID tags that might be embedded in items such as clothing and shoes.

In addition to tracking people, an RFID tag carrying product information would also permit surreptitious inventorying of their bearers. An attacker scanning the RFID tags contained in personal items could in principle gather information about a victim's clothing, medications, memberships and financial status, and so forth. This presents a clear potential for privacy violations.

Protecting Consumer Privacy

Many technical solutions have been suggested for protecting consumer privacy threatened by RFID tags; however, no single solution is likely to be completely satisfactory. A combination of these solutions may prove to be the best. Some suggested approaches to address the RFID privacy concerns are as follows:

The "Kill" Command

The simplest approach for the protection of consumer privacy is to "kill" RFID tags before these are placed in the hands of consumers. A tag can be killed by sending it a special "kill" command which instructs the tag to self-destruct. A killed tag is truly dead; therefore, the potential to use the associated data dies with it.

There are many environments, however, in which "kill" commands are unworkable or undesirable for privacy enforcement. Many of these applications will require that tags still be active while in the consumer's possession. For example, the stores may wish products to have tags scanable if the products are returned as defective.

The Faraday Cage

An RFID tag may be shielded from scrutiny by using a "Faraday Cage" – a container made of metal mesh or foil that is impenetrable by radio signals. However, the Faraday cage represents only a partial solution to consumer privacy as it does not block the tags working at lower frequencies. In addition, there is a vast range of tagged objects that cannot be placed conveniently in containers.

The Blocker Tag

The blocker tag is an approach of shielding tags from view by blocking/disrupting the operation of RFID readers. The consumer could carry a blocker tag that impair nearby readers by simulating the signals of all possible RFID tags.

However, the blocker tag approach may be considered as illegal in many countries and it could cause severe disruption of all nearby RFID systems, even those in legitimate applications where privacy is not a concern.

Selective Blocking

In selective blocking, a blocker tag blocks selectively by simulating only selected subsets of ID codes in a designated "privacy zone". The selective blocking enables the consumers to hide certain tags from scanning or reveal those same tags for scanning, when they want to do so. By allowing ID prefixes to be rewritten, tags can be moved in or out of "privacy zones" protected by various blocker tags. The readers which use tree-walking singulation algorithm to read unique tag data are the targets of this blocker tag. This algorithm is used by virtually all the readers in the UHF frequency and, therefore, is the most effective in blocking these types of readers. The blocker tag mechanism can also be implemented for the ALOHA algorithm, which is chiefly used by all 13.56 MHz frequency readers.

The Smart Tag

The smart tag is another approach in which the tag uses built-in features to protect the consumer privacy, while providing the desired active functionality. This typically involves the use of cryptographic methods. Two of such proposed methods for constructing smart tags are hash-lock method and re-encryption method. In hash-lock method, the tag is locked and it refuses to reveal its ID until it is unlocked; whereas in re-encryption method, the tag serial numbers are encrypted with a law-enforcement public key.

While hash-lock and re-encryption are effective approaches for protecting consumer privacy, constructing smart tags based on these approaches is exceptionally challenging to design, given the severe cost constraints on the basic RFID tag.

CONCLUSIONS

- RFID has developed into a mature technology to provide solutions to identification problems in many industries. It offers powerful benefits for businesses and consumers alike, and it is expected that the advancements in the technology will steadily bring more. It shows all the signs of having the potential for widespread use.
- RFID technology offers end-to-end product visibility and significant cost reduction benefits in supply-chain industry. With the support from major industry players, it is poised to revolutionize the operation of global supply-chains over the next few years.
- The range of RFID application types is continuously expanding. Some application types are already mature and being used commercially; other promising types are currently in the prototype stage.
- A significant challenge relates to standards. Co-existence of various standards and balancing of industry interests with broader standardization goals is going to be critical to the success of the industry. However, recent standardization efforts have opened new opportunities for RFID technology and, with the emergence of EPCglobal, standards-based RFID deployment is becoming a reality.
- Some of the RFID benefits create a new potential for infringements of consumer privacy that might present issues regarding RFID use in some situations. However, both tag-level and reader-level schemes have been invented to deactivate the readability of a tag. Therefore, a combination of technical and policy approaches can offer a solution to the privacy issues that can be broadly accepted by all the interested parties.
- RFID technology promises to change our world and it has the capability of making a paradigm shift. Likely, future shoppers will walk through checkout lanes, registering their purchases and paying automatically, and will never wait in line or interact with clerks.

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A NOVEL FOUNDATION DESIGN OVER EXPANSIVE SOILS IN SAUDI ARABIA

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ABSTRACT

It is reported that structures placed on shales of Tayma, Tabuk, Madinah and Al-Ghat regions in the Kingdom of Saudi Arabia are seriously affected due to expansive nature of the shales. Presence of highly plastic clays in Hofuf (an oasis in the eastern part of the Kingdom) indicated existence of potential expansive soil problems in these regions. Hofuf is notoriously known as the area with expansive clay problem and finds mention in text books on the subject also.

B.R.A.B (Building Research Advisory Board) Design Manual, a publication of Federal Housing Authority of USA was used to design the Stiffened Slab Waffle foundation system to address the heaving problems under the foundations of expansive soils.

In this paper, a case history is presented encompassing the experiences of this project vis-à-vis geotechnical complexities encountered at the project site, decision to adopt the Stiffened Slab Waffle Foundation to address the swelling clay problem underneath the foundations, development of design procedures and finally construction & performance track record of the same.

INTRODUCTION

By pouring concrete in the foundations for Barracks of an important government project in Hofuf, on Sunday the 7th February 1999 (21 Shawwal 1419 A.H.), Saudi Oger Ltd became the pioneer builder of the first ever 'Stiffened Slab Waffle Foundation' in the Kingdom of Saudi Arabia. This new foundation system was built under a total of 56 nos. (out of a total of 218 nos.) of facilities in Zones: 3 and 8 only, that is in only two Zones out of a total of eight Zones

This new type of foundation system is the State-of-the-Art solution for countering swelling problems underneath foundations due to presence of deep layers of moderate to high potential expansive clays. This especial kind of foundation system built for the project is first of its kind in the Kingdom as well as in the region. Thus, the Kingdom becomes only the third country in the entire world, only after USA & Australia, to have built this type of special foundation system. This paper presents a brief review on this project.

OVERVIEW OF EXPANSIVE SOILS PROBLEM

Expansive Soils have a tendency to undergo excessive volume change upon contact with water and exert upward pressure (heaving) underneath foundations resulting in damages to the structural elements. According to F. H. Chen [2] it appears that expansive soil is the cancer of Soil Mechanics. And, similar to cancer, the seriousness of the problem has been discovered only in recent years.

He further adds this problem was not recognized by Soil Engineers until the later part of 1930. Prior to 1930, most of the lightly loaded buildings in the United States

consisted of dwellings which could withstand considerable movement without exhibiting noticeable cracks. By 1930 brick veneer residences became widely used. It was then that the owners found cracks developing in the brick courses. These were then attributed to shoddy construction without recognition of the role of the expansive soils.

The U.S. Bureau of Reclamation first recognized the expansive soil problem in 1938 in connection with a foundation for a steel siphon at their Owyhee Project in Oregon. Since that time, engineers realized the cause of damage to be something other than settlement or shoddy construction.

It is reported [3], within the United States alone, annually expansive soils are responsible for billions of dollars worth of damages to man-made structures. It is said, although perhaps not as sudden or traumatic as an earthquake, tornado or landslide, expansive soil causes more damages (in the US) to buildings, highways, etc., than the combined effects of the other aforementioned natural calamities

In Saudi Arabia it is reported that structures placed on shales of Tayma, Tabuk, Madinah and Al-Ghat regions are seriously affected purely due to expansive nature of the shales. Presence of highly plastic clays in Hofuf indicated existence of potential expansive soil problems in this region also.

Besides the USA and Australia, expansive soil is found to be troublesome in large areas of India and some parts of Pakistan, parts of Africa and the Middle East including Saudi Arabia. Many other parts of the globe like, Peru, England, and France are also affected by this menace. **Montmorillon** in Central France is crdeited for having **Montmorillonite**, a known expansive soil, named after it [5].

EXPANSIVE SOILS PROBLEM IN SAUDI ARABIA

Slater [10] has presented a very general map, for potentially expansive soils of the Arabian Peninsula. However, the map lacks data on field exploration and laboratory testing for the suspected areas.

Researchers at King Saud University, Riyadh and King Fahad University of Petroleum and Minerals, Dammam have undertaken lots of painstaking works on the subject. The King Abdul Aziz City for Science and Technology (KACST), has sponsored all these research works. Dhowian [4] has carried out in-depth study, evaluation, and documentation of Saudi expansive soils. According to him, the expansive soils found in Saudi Arabia mainly consist of two distinct materials, namely:

- Sedimentary Rocks, and
- Clayey Soils

Expansive Sedimentary Rocks include shales, claystone, and siltstones that exhibit some degree of lithification, and possess the extrinsic and intrinsic properties that cause volume change. The shales with various degree of weathering prevail in a strip adjacent to the west boundary of the Arabian Shield. The strip starts around Al-Ghat and extends to the North-West enclosing the Tabuk and Tayma regions. Expansive Clayey Soils are usually found in small areas scattered in the Arabian Shield and Arabian Shelf, such as the Madinah and Hofuf regions.

Table 1 shows the formation, geological age and topography of the regions.

The average geotechnical properties of plasticity characteristics of both Shales and **Clayey Soils** are represented in Table 2. Other properties namely the Index Values and the Suction Parameters of samples from various regions of the Kingdom are represented in Table 3. According to Dhowian [4] the log of soil suction versus water content behavior can be approximated by a straight line in the following manner:

$$\text{Log } \Psi = A - B\,W$$

Where,

Ψ = Soil suction

A, B = intercept and slope of log suction water content

W = Water Content, %

Thus, from known initial and final water contents, the range of change in the soil suction as a result of swell, can be determined by means of the above equation, and correspondingly the values of A and B, are given in Table 3.

Table 1: Description of Expansive Soils in Saudi Arabia [4]

SNO	REGIONS	FORMATION	GEOLOGICAL AGE	TOPOGRAPHY
1	**HOFUF**	Calcareous Clay (Marl)	Upper and Middle Miocene	Terraces
2	**MADINAH**	Alluvial Deposits, Colluvial Deposits	Tertiary and Quaternary	Terraces
3	**AL-GHAT**	Alluvial Deposits over weathered Shale (Dhruma Formation)	Quaternary and Middle Jurassic	Terraces
4	**TABUK**	Alluvial Deposits and weathered Shale (Tabuk Formation)	Quaternary	Terraces and Low Hills
5	**TAYMA**	Weathered Shale (Tabuk Formation)	Quaternary	Terraces and Low Hills

Table 2: Geotechnical Properties of Typical Expansive Soils in Saudi Arabia [4]

ITEMS	SHALES				CLAYEY SOILS		
	AL-Ghat		Tabuk	Tayma		Madinah	
	Clay Shale	Silty Shale	Clay Shale	Silty Shale		White Clay	Green Clay
Dry Unit wt γd, kN/m³	18.50	18.50	19.50	19.40	**14.20**	12.60	12.20
Water Content, Wn, %	19	12	4.50	2.30	**14**	33.10	59.10
Liquid Limit, LL,%	65	46	61	38	**60**	82	105
Plastic limit PL, %	30	21	27	25	**24**	37	39
Plasticity Index, PI	35	25	34	13	**36**	45	66
Shrinkage Limit, SL %	21	16	23	20	**18**	28	16
Percent Sand, %	--	3	7	9	**23**	2	7
Percent Silt, %	28	52	48	68	**40**	30	29
Percent Clay, %	72	45	45	23	**37**	68	64
Specific Gravity, Gs	2.78	2.70	2.78	2.75	**2.69**	2.74	2.76
Group Symbol	CH	CL	MH	CL-ML	**CH, MH-OH**	CH	CH
Activity, Ac	0.50	0.55	0.75	0.55	**0.97**	0.70	1.00

EXPANSIVE SOILS OF THE PROJECT SITE

The project Site was located about 12 km west of Hofuf. The upper strata, known as **Hofuf Formation** of the **upper Miocene** consist of terrestrial sediments. These marine strata, known as **Dam Formation**, consist of limestone, marls, and clays of the **middle Miocene**. It is overlain by continental deposits of conglomerate, sandstone, sandy limestone, sandy marl, and sandy shale of the Hofuf Formation. The upper beds consist of sandy, fresh water limestone. It is quite heterogeneous and both the thickness and lithology vary considerably [11].

According to the results of investigations in the report by a Geotechnical Consultant, the subsurface strata at the site predominantly consist of deep layers of either Fat Clay or highly to moderately weathered & fractured Limestone. This, of course under a cover of Silty Sand, with Limestone fragments and Calcareous Clay. The thickness of this cover, in general, was observed to be 1.0 meter. In addition, the N-Values, observed through Standard Penetration Tests performed on overburden soil layer, were recorded in the range of 28 blows per 30 cm to in excess of 50 blow for 30 cm penetration of the sampler. This indicated medium dense to very dense condition of the strata. The N-Values obtained in Fat Clay layers mostly indicated 'Refusal' conditions. Thus, the Clay is obviously pre-consolidated. However, upon ingress of water to the Clay layer, change in its volume and its swelling is likely to occur. Laboratory tests performed on representative samples taken from the site show that upon saturation the Free Swell of Clay layers varied between 1.60 % and 3.0 % and such swelling developed an upward pressure ranging between 125 kPa (2608 Psf) to 300 kPa (6258 Psf) as against Allowable bearing pressure of 175 kPa (3651 Psf) only. A Plate Load test, performed on the clay layer at test elevation of – 1.30 meters, showed that upon soaking the swelling of Clay was 18.90 mm, with moisture penetration depth of 35 cm resulting in about 5.40 % swell. More over, in some areas, the clay layer underlies a cover of light brown, medium dense to dense silty/clayey sand. The thickness of the sandy cover is mostly restricted to1.0 meter.

According to the Geotechnical Investigation Report, foundation on Fat Clay (expansive clay) should be rigid enough to sustain the impending swelling (heaving) pressure. The Report suggested to use **Stiffened Slab Waffle Foundation** System, prepared by **B.R.A.B (Building Research Advisory Board)** under the aegis of **Federal Housing Authority (F.H.A)** of the United States. Alternatively, the report also suggested changing the location of the project Site, altogether.

Table 3: Suction Parameters of Expansive Soils of Saudi Arabia [4]

REGIONS	SOIL TYPES	CONSISTENCY			SUCTION PARAMETERS	
		LL	PL	PI	A	B
TAYMA	SHALE	38	27	11	1.85	- 0.057
TABUK	SHALE	61	27	34	1.61	-0.025
AL-GHAT	SILTY SHALE	37	22	15	1.67	-0.017
AL-GHAT	CLAY SHALE	67	32	35	2.10	-0.025
MADINAH	GREEN CLAY	105	39	66	2.28	-0.030
MADINAH	WHITE CLAY	82	37	45	2.34	-0.045
HOFUF	**CALCAREOUS CLAY**	**60**	**24**	**36**	**2.16**	**-0.033**

FOUNDATION CONSIDERATIONS ON EXPANSIVE SOILS

Experts around the globe have a consensus about the fact that if a soil is classified as having a Low Swell potential, standard or regular construction practices vis-à-vis foundations may be followed. However, if the Soil possesses a Marginal or High Swell potential, precautions are needed to be taken. This may entail one of the following [12]:

- **Changing the Nature** of the expansive soil by such measures as Compaction Control, Pre-wetting, installation of Moisture Barriers and Chemical Stabilization.
- **Replacing the Expansive Soil** from under the foundations with suitable fill material, compact the fill then construct the standard or regular non-rigid foundation system s like the spread footings, etc.
- **By-pass the active zone** of the expansive soil and construct Deep Foundations on non-swelling strata e.g, Piles or Drilled Piers.
- **Design and construct a Rigid Foundation System** over the expansive soils, which has an inherent ability and capacity to withstand differential movement due to heaving of the expansive soil, without causing any damage to the superstructure.

It is of interest to note here that each of the above propositions has its own limitations. And, that each option is best suited depending upon the nature & gravity of swelling problem at the construction Site in question. Appropriate measures, best suited to the site conditions, are suggested.

STIFFENED SLAB WAFFLE FOUNDATION

Three decades ago the prevailing philosophy was to attack these 'natural nuisances' of expansive soils with bulldozers, chemicals, and concrete. But now the researchers reconsider that old philosophy, suggesting that with a better identification and preventive design techniques we might now learn to co-exist with these 'natural nuisances'. Design of **Stiffened Slab Waffle Foundation**, developed by **B.R.A.B** in the US in 1968, is one such design technique which ensures safety and safe performance of structures built over expansive soils and in a way allows co-existing with these natural nuisances of expansive soils.

Fundamentals of B.R.A.B Design Procedures

The design procedures, as outlined in the **B.R.A.B Design Manual** [1] consist of three basic operations, namely:

- Selection of appropriate foundation (Slab) Type
- Dimensioning the Slab, or its lay out
- Reinforcing the Slab

To perform the above outlined operations the designer has to analyze many factors that directly or indirectly influence the design. The important ones are:

- Soil properties of the ground on which the Slab is to be supported.
- Type of Superstructures, and
- Quality Control in materials used for construction

Selection of Slab (foundation) Type

B.R.A.B Manual deals with design of Foundations over both expansive & compressible soils. Therefore, it allows for selection of a Slab Type (for design of Foundations) appropriate to the soil types and conditions at the Site. The various Slab types considered are:

- **Type I :** Un-reinforced
- **Type II:** Lightly Reinforced against shrinkage and temperature cracking
- **Type III:** Reinforced and Stiffened, and
- **Type IV:** Structural, not directly supported on ground.

As per Table 1 of the B.R.A.B manual, if [1]:

$PI > 15$, and $qu/w \geq 7.5$,

Then a **Type III** Slab can be used which exclusively addresses the expansive soils problems.

Design of Type III Slabs

Slab Type III is exclusively focussed to addressing foundation design over expansive soils. It is used with soils which in all likelihood will undergo substantial volume changes with time. Use of spread footings or any other conventional footings is not advisable on such soils. In such types of Slabs **(Stiffened Slab Waffle Foundation)** loads are distributed by the Slab over its entire ground-support area. This reduces the bearing stresses on the soil and also forces the foundation, the Slab, and the super-structure to act as a monolithic structure; somewhat like a rigid boulder in a soft mass of ground.

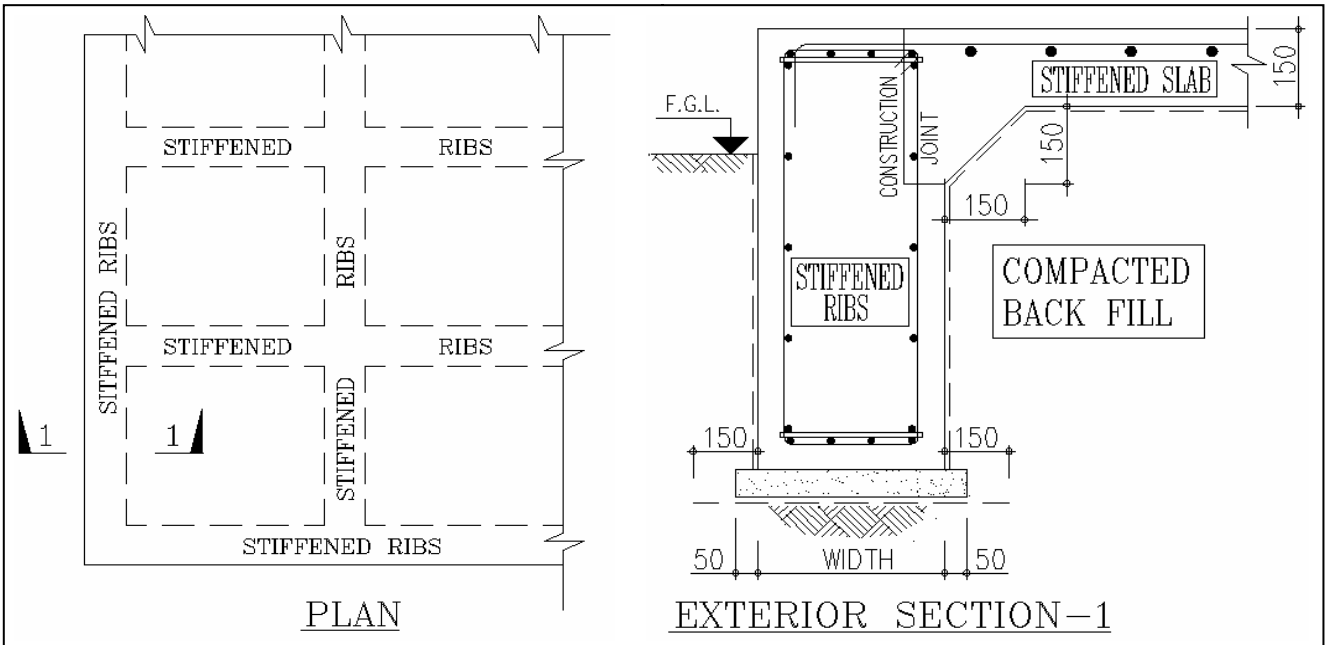

Figure 1: A Typical Detail of Stiffened Slab Waffle Foundation

Plate 1: Excavation & Rebar Placing For Stiffened Slab Waffle Foundation at the Site

Plate 2: Concrete Placing In Stiffened Slab Waffle Foundation at the Site

The super-structure, depending upon its rigidity, imposes limits on the maximum slab deflection that can be tolerated. The climate, on the other hand, affects the pattern of distribution of the soil bearing stresses & hence the distribution and intensity of stresses and resultant deformation of the slab.

Design Parameters Used For the Project

For design of foundations, for the Project in question, the following design parameters were used:

- Bearing Capacity:175 kN/m²
- PI (Plasticity Index): 33
- Free Swell: 3.0 %
- qu: 300 kN/m²
- Cw (Climate Rating): 17

Based on the above parameters, the value of Support Index C was interpolated to be 0.80, using Figure 6 of B.R.A.B manual [1]. It was later modified to 0.85 using provisions allowed in [1], to effect some economy in the design. Spread sheets were prepared using sequential logic of the procedures as laid down in B.R.A.B Design Manual to perform design calculations for each facility. Attached sketch, Figure 1A (foundation lay out of one of the Facilities of the Project) is in fact a typical detail of the **Stiffened Slab Waffle Foundation** System used in order to counteract the heaving forces of the expansive soils beneath the foundations. The Plate-1 shows the foundations rebars laid out for the ribs and Plate-2 shows the ribs already poured at site.

CONCLUSION

1. Stiffened Slab Waffle Foundation System, were used for design of foundations over expansive soils for 56 out of 228 facilities in 2 out of a total of 8 Zones of the project Site in Hofuf.
2. Saudi Arabia becomes only the third country in the world, after USA & Australia, to have adopted this type of foundation system solely to address the swelling & heaving problems of expansive soils.

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iDEN TECHNOLOGY AND ITS BENEFITS

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ABSTRACT

There has been a lack of iDEN knowledge in the Middle East and Asia markets. This paper is written to address the awareness, comparison and benefits of the IDEN Technology to other telecom technologies. The intent is that after reading this paper the reader should become conceptually very clear on the iDEN technology and should be able to easily differentiate iDEN with other technologies. This is accomplished by going over the basics of iDEN, its spectrum efficiency and Push-To-Talk comparisons with other technologies.

INTRODUCTION

The outgrowth of the wireless communications market has produced vast opportunities to enhance and improve the communications between individuals. Because of this growth, the need to optimize Radio

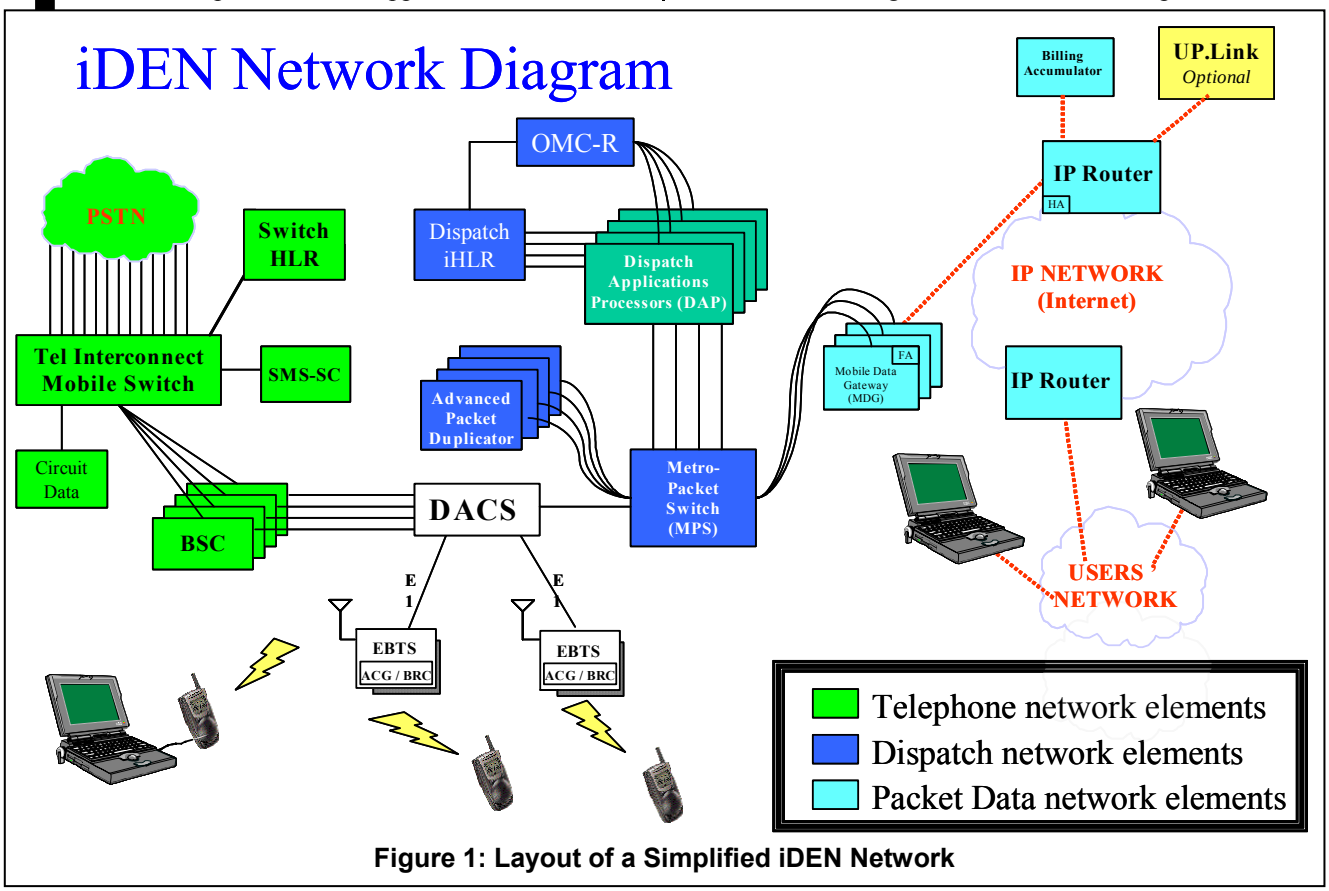

Figure 1: Layout of a Simplified iDEN Network

Frequency (RF) spectral resources and provide ever-increasing services is essential.

To support the increase in wireless services while making best use of available resources, the iDEN system capitalizes on the fact that communications can be:

Half-duplex — where one user is transmitting (talking) and other users are receiving (listening)
Full-duplex — where there is an open bi-directional link that allows full two-way communication

Many times communication does not require a full-duplex link. Messaging, paging, some forms of data communication and structured voice communi¬cation are, or can effectively operate in, half-duplex mode.

Traditional telephone conversations and more intensive data links require the ability to interrupt; that requires full-duplex operation.

The iDEN system provides both full and half-duplex operations. This melding of communications methods allows much of the voice traffic to be run in half-duplex mode, while providing full-duplex functionality when required.

As part of the ongoing effort to support the outgrowth in wireless communi¬cation, the iDEN system is an integration of traditional Push-To-Talk (PTT), half-duplex, analog radio technology and feature-rich, full-duplex digital cellular communications. This integration of mobile communication technol¬ogies provides state-of-the-art functions and benefits to mobile users while optimizing the available infrastructure resources.

The iDEN system consists of many components and pieces of physical hardware. The components and hardware are located throughout the local service coverage area. To simplify integration, the equipment uses industry standards for physical size, power requirements, and interface connections wherever possible. Each major component listed has sub-systems that perform more specific tasks. The layout of a simplified iDEN network is shown in Figure 1.

IDEN SYSTEM

The iDEN Network consists of three sub-systems which are briefly outlined next.

Interconnect Or Telephone Sub-System

The MSC is the telephone switch for mobile originated or terminated traffic. Major functions of the MSC are to Control and Interface to the PSTN, Call Processing for Interconnect calls, Echo Cancellation for Voice Calls (with associated equipment), Provisioning of Subscriber Supplementary Services and Authentication of Subscriber Units

During an Interconnect call MSs are validated by the Home Location Register (HLR) database. The HLR contains the master database for all subscribers, supports multiple MSCs and contains the basic and active supplementary services for each subscriber

MS units are tracked via fixed geographic Interconnect Location Areas (ILAs). These areas are defined by the system operator based on the coverage area of the EBTS sites. Location data is stored in the VLR. The functions includes Subscriber database local to the switch for fast access during call set-up, contains most of the HLR information about the active MS units and in addition most recent location information within the coverage.

Dispatch Sub-System

The main network elements of the Dispatch sub-system are the DAP, iHLR, MPS and APD. The iDAC is used for long-distance dispatch.

The Dispatch Application processor (DAP) provides Dispatch signaling (registration & call setup). It tracks the dispatch location of subscribers in the iDEN network, collects billing information for dispatch services, and functions as the IMEI-IMSI server for the iDEN subscribers. A subscriber cannot join the iDEN network until it has received an IMSI assignment from the DAP.

Advanced Packet Duplicator (APD) duplicates VSELP voice packets for simultaneous broadcast to subscribers involved in dispatch call. It connects to the MPS with four 10 Mbps HSSI interfaces. Each APD pair is controlled by a DAP, configured for N+1 redundancy. In a typical configuration if one APD fails, the second APD will be capable of supporting all of the voice traffic associated with the given DAP.

Metro Packet Switch (MPS) is responsible for switching dispatch signaling and voice frames between the DAP, APD and EBTS equipment.

Enhanced Base Transceiver System (EBTS) provides the RF interface to the iDEN subscriber units; Translates E1 frame relay, Mobis and SCI information to the RF interface; Collects traffic statistics for the RF resources that it manages and manages RF resource requests for telephony, packet data and dispatch services.

Packet Data Subsystem

The main network elements of the Packet Data sub-system are the MDG, Home Agent and Billing Accumulator. The MDG is a Primary Packet Data system component. The MDG is a system entity that provides Mobile subscribers Packet Data functionality within the iDEN system infrastructure.

BENEFITS OF IDEN

Traditional PTT radio communications in corporate and municipal environments was limited by the number of radios and Federal Communication Commission (FCC) licensing. These restrictions limited the coverage area, contact outside the assigned, licensed mobile units, and provided little privacy. The iDEN system:

1. Removes end-user FCC licensing requirements.
2. Opens communication to other subscriber corporations and all telephones.
3. Increases the coverage area.
4. Allows private and group calling.
5. Optimizes RF resources.
6. Improves quality with higher frequencies and digital technology.

Because of the finite availability of the Radio Frequency (RF) spectrum and a need to optimize this resource, iDEN technology increases the efficiency of a single 25 kHz RF carrier by applying up to six times the traffic of an AMPS Cellular carrier. iDEN technology by far has the best spectrum efficiency as compared to any technology that exists out in the market.

In addition to the increased channel efficiency, an iDEN system may be deployed to support communications outside the provider's network (roaming). The telephone-style interconnect capability allows users to roam seamlessly throughout linked service areas. A user may place and receive calls as if the Mobile Station (MS) is on its home system. This also allows the service provider to offer an integrated service that includes:

- Messaging (Short Message Service)
- Private, Two-way & Group Call Cellular Telephony Service
- Voice Mail
- Data Networking (Intranet, Virtual Private Network (VPN), Internet).

Since the iDEN system uses digital technology, it provides clear voice quality, interference is reduced and voice quality is enhanced.

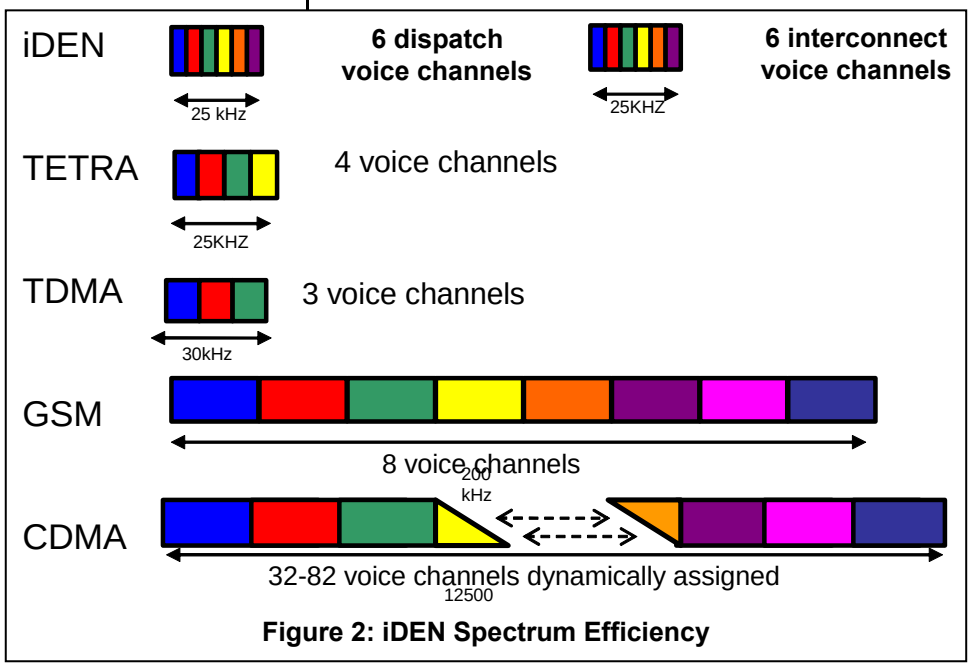

Figure 2: iDEN Spectrum Efficiency

PTT ON NON-IDEN TECHNOLOGIES

1. Comparing PTT on CDMA and GSM/GPRS to iDEN

Both have rich feature set

PTT Server-based Solutions for CDMA and iDEN introduce some new features:

- Instant Messaging
- Presence
- User controlled selective Group Call

Call Setup is a major performance issue

- CDMA: Initial Call Setup will vary greatly
- GSM/GPRS: Consistent, but longer, initial call setup.

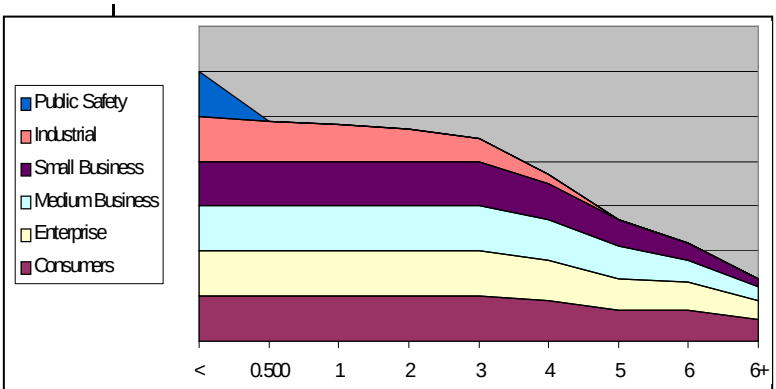

Figure 3: Initial PTT Delay: 5-6 Seconds average; Standards work can improve on this

2. PTT Performance Issues - CDMA

CDMA networks are not designed for PTT

- Immediate Initial Call Setup not supported in RF signaling
- Additional issue of variability from initiating and target subscribers being in dormant mode
- Dormant mode
  - CDMA 1X handsets placed in dormant mode after 20 seconds inactivity
  - Requires more than 2 seconds to wake up and handshake with the network

GSM/GPRS Initial call setup delay (PTT → Talk Permit) simulation estimate is about 5.5s average

SUMMARY

1. Five distinct services (dispatch, telephone interconnect, short message service, circuit & packet data) provided through a single subscriber radio unit, resulting in highest ARPU in the wireless industry today
2. Spectrum efficiency equivalent to 2 additional voice channels over TETRA and 3 additional voice channels over GSM within 25 KHz, allowing for additional subscriber loading and / or billable minutes of use
3. Non-Contiguous frequency capable RF technology, providing channel acquisition flexibility
4. Reasonably priced RF channels
5. 2.5 G technology platform today with multi-network system dispatch service interconnection in 2002, which provides a lower cost alternative to telephone interconnect service.
6. Support of 911 emergency and call monitoring features on both dispatch and telephone interconnect services which comply with U.S. Regulatory Requirements for wireless service operators.

IMPORTANT GOVERNMENT WEBSITES

DEPARTMENT	WEBSITE	DEPARTMENT	WEBSITE
Board of Investment	http://www.pakboi.gov.pk	National Reconstruction Bureau	http://www.nrb.gov.pk
Central Board of Revenue	http://www.cbr.gov.pk	National Savings Organization	http://www.savings.gov.pk
Civil Aviation Authority	http://www.caapakistan.com	National Tariff Commission	http://www.ntc.gov.pk
Export Promotion Bureau	http://www.epb.gov.pk	Overseas Employment Corporation	http://www.oec.gov.pk
Federal Board of Inter/Sec Education	http://www.fbise.edu.pk	Overseas Pakistan Foundation	http://www.opf.gov.pk
Federal Bureau of Statistics	http://www.fbs.gov.pk	Pakistan Housing Authority	http://www.pha.gov.pk
Geological Survey of Pakistan	http://www.gsp.gov.pk	Pakistan International Airline	http://www.piac.com.pk
Government Forms	http://www.forms.gov.pk	Pakistan Medical Research Council	http://www.pmrc.gov.pk
Government of Pakistan Info	http://www.pak.gov.pk	Pakistan Meteorological Department	http://www.met.gov.pk
Government of Pakistan Portal	http://www.pakistan.gov.pk	Pakistan Post	http://www.pakpost.gov.pk
Government of Punjab	http://www.punjab.gov.pk	Pakistan Railways	http://www.pakrail.com
Government of Sindh	http://www.sindh.gov.pk	Pakistan Science Foundation	http://www.psf.gov.pk
Higher Education Commission	http://www.hec.gov.pk	Pakistan Software Export Board	http://www.pseb.gov.pk
Karachi City Government	http://www.karachicity.gov.pk	Pakistan Sports Board	http://www.sports.gov.pk
Lahore City Government	http://www.lahore.gov.pk	Pakistan Telecom Authority	http://www.pta.gov.pk
Ministry of Finance	http://www.finance.gov.pk	Pakistan Telecom Company Limited	http://www.ptcl.com.pk
Ministry of Foreign Affairs	http://www.forisb.org	Pakistan Television	http://www.ptv.gov.pk
Ministry of Interior	http://www.interior.gov.pk	Pakistan Tourism Develop. Corp.	http://www.tourism.gov.pk
Ministry of Labor/Overseas Pakistanis	http://www.labour.gov.pk	Private Power & Infrastructure Board	http://www.ppib.gov.pk
Ministry of Privatization	http://www.privatisation.gov.pk	Privatization Commission	http://www.privatisation.gov.pk
Ministry of Religious Affairs	http://www.mra.gov.pk	Radio Pakistan	http://www.radio.gov.pk
Ministry of Science and Technology	http://most.gov.pk	Securities & Exchange Commission	http://www.secp.gov.pk
National Accountability Bureau	http://www.nab.gov.pk	Small/Medium Enterprise D Authority	http://www.smeda.org.pk
National Assembly of Pakistan	http://www.na.gov.pk	State Bank of Pakistan	http://www.sbp.org.pk
National Database & Reg. Authority	http://www.nadra.gov.pk	State Engineering Corporation	http://www.sec.gov.pk
National Library of Pakistan	http://www.nlp.gov.pk	Water & Power Develop. Authority	http://www.pakwapda.com

CAUSAL PATH MODELLING TO TEST THE HYPOTHESES IN CONSTRUCTION ECONOMICS AND MANAGEMENT RESEARCH

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ABSTRACT

Construction Economics and Management is part of science that is self correcting body of knowledge and eventually appeals to evidence, which means that construction research hypotheses are subjected to test. One of the most important parts of the analysis stage of a research project is to be clear about how the research questions are translated into the data analysis procedures and then to present the analysis so that it tells a clear logical story to the reader. In experiments this logic is often specified by the research hypotheses, and built into the research design. There are several methods that help in developing a statistical model to test the hypotheses and Causal Path is one of them. Causal Path analysis developed by Wright in 1921, works on a theoretical knowledge and is a recognised quantitative technique in social, medical demographic, and construction sciences to test the hypotheses. This paper aims to show how the theoretical assumptions and hypotheses for construction research can be presented in a path diagram, and how the diagram can be used to aid the design of a study and the analysis and interpretation of the data. Examples and data presented in the paper are from "A Causal Path Model to Measure the Effects of Professional Training upon Time Overruns in Saudi Construction Projects" developed by author in 2003.

INTRODUCTION

Fellow and Liu (1997) believes that explanatory theories of science can be developed purely through reasoning, without reference or recourse to the observations yielded by experience or experimentation. However, Rosen (1982), Poper (1989) and Kerlinger (1986) maintain that such pure reasoning is inadequate, and it is essential to use experience from observation and experimentation to determine validity or falsity of a scientific theory. Presently three principal approaches are considered acceptable for construction research. These are (a) quantitative methods (b) qualitative methods and (c) a combination of both quantitative and qualitative methods, known as a mixed approach. Seymour and Rooke et. al. (1995) strongly argued for the use of "interpretive" (qualitative) approaches over the "rationalistic" (quantitative) approaches often used for Construction research. Qualitative approaches yield an investigation that is primarily concerned with meaning as opposed to causality. This unscientific approach was bitterly criticised by the leading researchers such as Runeson (1997) and Harris (1998). On the other hand, despite criticising, Raftery et al. (1997) were advocates of the combined approach.

A study of abstracts of papers published in the Construction Management and Economics (CME) journals from 1983-1996 revealed that 57% researchers utilised quantitative, 8% qualitative, and 13% mixed methodological approaches. The remaining papers were classified as "non-research" papers (Loosemore et al., 1996). A review of the ARCOM proceeding for the period 1999-2001 shows that the trend of qualitative and mixed mode approaches has increased slightly. However, it remains the case that the quantitative approach that often requires statistical models to test the hypotheses dominates Construction research.

There are several methods that help in developing a statistical model to test the hypothesis and Causal Path is one of them. This paper aims to present the techniques to

develop a Causal Path Model for Construction research, utilising examples and data from model developed by author in 2003.

Causal Path Modelling

The term "Path Analysis" was introduced by Wright (1934) in connection with decomposing the total correlation of certain variables upon a single response (dependent) variable or a number of such response variables in a causal system. He considered that presentation of relationship through a diagram is more useful than the partial correlation method. Wright developed the statistical techniques to determine the path coefficient *"p"*, and proved that these coefficients are equal to standardised partial regression coefficients.

In 1960, Wright published two more papers, describing the method to more complicated or special circumstances (Wright, 1960). Causal path models were extensively used in the United States for studies of Social Mobility (Blau and Duncan, 1967) and. Abdullah and Shafiq-Ul-Islam (1991) used path analysis to develop models for social and demographic research.

Causal Modelling and Construction Research

Using path analysis techniques for the first time in Construction research, Shaddad and Pilcher (1984) developed a conceptual model to evaluate the *"influence of management on construction system productivity"* in 1984. Later on Brown and Adam (2000) developed a causal path model to measure the *"effect of project management performance on construction outputs"*. Recently author applied it to measure the *"professional training effects upon time overruns in Saudi construction projects"* (Amjad, 2003).

Principals of Path Analysis

The principal of Path analysis is, that any correlation coefficient between two variables, or a gross, or overall measure of empirical relationship can be decomposed into a series of parts: separate paths of influence leading through chronologically intermediate variable to which both the correlated variables have links (Kothari – 1998). Path analysis makes use of path coefficients derived through a series of simultaneous multiple regression equations.

It works on a "priori theoretical knowledge" and the technique requires the assumption that there are linear additive, and symmetric relationships among a set of variables which can be measured at least on a quasi – interval scale (Kothari – 1998) and (Boyle – 1970). In order to operate a causal path model, it is necessary to transform the acquired data to standard scales, so that the typical effect of the constant, "a", in the linear regression equation could be converted to zero. The technique permits the direct use of the correlation coefficient as the measure of causal path coefficient.

Following are the general rules and assumptions, which should be observed in path analysis.

1. The causal ordering cannot be decided by an empirical analysis of the data. It must be determined from a priori theoretical knowledge (Atkins, 1980).
2. Causal ordering system generally rules out the chance of circular causation between variables. However, the analysis which accommodates the circular causation is very complicated (Atkins, 1980).
3. It is assumed that there is no interaction between the variables included in a path diagram (Atkins, 1980).
4. In assessing the affect of an explanatory (regressor) variable on the dependant (response) variable, all the variables causally prior to the explanatory should be controlled (Little, 1979).
5. The dependent (response) variable must be the last variable in a causal chain (diagram). Variables causally posterior to the dependent should not be controlled (Little, 1979).

Variables in a Path Model

A path model deals with explanatory, dependent, intervening and extraneous variables. Explanatory variables are viewed as the ultimate causal influences, which act upon the response variable. If one variable depends upon or is a consequence of the other variable, it is termed as a dependent or a response variable. In a path model those are viewed as intervening variables through which explanatory variables exert an indirect influence upon the dependent variables. (Kothari, 1998). For example, If "X" is causing a change in "Z" through "Y", then "Y" is described as intervening variable, whereas "X" as explanatory and "Z" as dependent variables. In some cases these variables may consist a set of variables; e.g. Abdullah and Shafiq-Ul-Islam (1991) used seven explanatory variables and Brown and Adams (2000) used three dependent variables in their models.

Certain variables always remain extraneous due to the impracticality of acquiring all of the conceivably relevant data. These are termed as extraneous variables (Kothari, 1998). Whatever affect is noticed on a dependent variable as a result of extraneous variables is technically described as an "experimental error". In path analysis such "experimental errors" are considered as the proportion of variance unexplained by the model (Atkins, 1980).

Selection of Variables For Causal Path Modelling

In a path model variables are selected from a priori theoretical knowledge. Generally, a small number of intervening variables which are speculated to be of significant importance in transmitting the influence to the dependent variable(s) are selected in addition to the desired

independent and dependent variables. In fact the selected variables address the research question.

While measuring the "professional training effects upon time overruns in Saudi construction projects" author examined the origination structure of Saudi Construction Industry (Amjad-1998), and considered that Client's representative is the one who provides all necessary information to the designer at design stage and plays a vital role in approvals during construction process. An exploratory research conducted by the author revealed that a relationship exists between the causes of time overruns and the role of the Client's representative which means that an effective role (better performance) of the Client's representative would reduce the effect of delaying factors and consequently would result in reduction of time overruns of Saudi Construction Projects. Whereas, literature revealed that poor performance in construction industry may be improved through professional / competency based training (Kumaraswamy, 1996 & 1997), (Khan, 1993) and (Cheng and Song, 1995). Hence, in the light of this "priori theoretical knowledge" the Level of Professional Training of Client's representative (LT) and Time Overruns of Saudi Construction Projects (TN) were selected as explanatory and dependent variables respectively.

In order to select the intervening variables, author followed the Bennett's (1991) theory which suggests that if construction projects are to be successful, managers must pay specific attention to the following five key areas:-

(i) Complexity
(ii) Project Size
(iii) Repetition
(iv) Uncertainty
(v) Speed and Economy

Clearly, these areas were valuable starting points in considering the set of intervening variables that need to be examined in an attempt to model the causal relationships between Training levels and Time delivery.

Adams and Brown (2002) argued that complexity, project size and repetition can be incorporated within a single variable termed technical complexity which can be termed as Design Complexity as well. Additionally, the features of uncertainty can be measured within a variable termed risk. Finally, the features of speed and economy can be encapsulated within a variable that measures procurement

To insure parsimony it was desired to minimise the number of intervening variables that are incorporated in the model. For this reason, the above logic was followed, and the specified intervening variables were selected as:-

(i) Design Complexity,
(ii) Risk and
(iii) Procurement System.

The client's representative has the opportunity to influence each of these variables. A priori assumption suggested that better the trained client's representative; the more positive will be the influence on each one.

Of the three variables identified above, risk was perhaps the most complex. Risk, itself, can be controllable or uncontrollable. A controllable risk is one which can be managed and controlled. Its probability is directly related to management's competency and to the performance of site personnel. Conversely, an uncontrollable risk lies outside the control of any of the parties to a project. Environmental risks such as adverse weather conditions and inflationary rises on material cost are typical uncontrollable risks. Bennett addresses this aspect of uncertainty by defining two constituent uncertainty components, namely, interference and variability. Interference concerns uncontrollable risk, whereas variability concerns controllable risk.

As a principle adviser it is the client's representative responsibility to identify controllable and uncontrollable project risk, and to take appropriate actions in order to minimise their effects. In order to efficiently address the risk variable that must be examined it was considered that it must be decomposed into three separate components that most appropriately relate to the main responsibilities of a client's representative in the Saudi Construction Industry. These three components were defined as follows.

i. **Risk effecting Design Complexity (RD):** These types of risks are generated owing to lack of necessary site investigations and affect the quality of design.
ii. **Risk effecting number of Variations (RV):** These types of risks are mainly generated owing to lack of co-ordination between different trades at design stage and cause errors in contract documents.
iii. **General Risk (GR):** This component considers the selection of technical and financial agencies to operate the project. Inappropriate selection generates a general risk of time overruns if these agencies default on their obligations. It follows that increased training would reduce the number of inappropriate selections made by clients representatives.

Although parsimony was a key concern, another intervening variable late approval(s) was included for completeness on the following basis.

Walker (1992) argues that projects must be managed through a number of critical decision points. In reality these key decision points materialise at approval gates or stages. Many approvals are required in order to progress projects. In Saudi Construction Industry, the client's representative holds responsibility for the approvals of detailed drawings, interim payments and equipment upon recommendation of consultants. Clearly, if these approvals are withheld or delayed, the probability of late project completion is greatly increased. Late approval is an issue in Saudi Construction Industry. It follows that increased training would reduce the number of late approvals that occur in a given project. For this reason, late approval(s) was included as an intervening variable in the model.

Hence, in total, the model included seven intervening variables as follows:

(i) Design complexity (DC).
(ii) Risk effecting design complexity (RD).
(iii) Risk effecting number of variations (RV).
(iv) General risk (GR).
(v) Procurement (PR).
(vi) Late approvals (LA).
(vii) Variations (VA).

Other variables not included in the model, were considered to be extraneous. Their influence relative to the specified variable set was estimated from the residuals.

Above example from author's model clearly demonstrates that how carefully the variables in a path model are selected from a priori theoretical knowledge.

Construction of a Causal Path Diagram

Path Analysis technique lays relatively heavier emphasis on the heuristic use of a visual diagram, technically described as a "Path Diagram". In a path diagram selected variables are drawn in such a way that explanatory and dependent variables are shown at the left and right hand accordingly, whereas intervening variables are shown in the centre. Then, based on a priori theoretical knowledge, these variables are connected by arrows, which represent postulated causal connections between the variables. Whenever (based on priori theoretical knowledge) it is postulated that one variable is affecting another, an arrow is drawn between these variables to connect them and the head of arrow represents the assumed direction of causation.

The path diagram provides a framework for the statistical analysis of the data and the interpretation of analysis. During analysis the hypothesised structure of interrelation provided by the path diagram can be modified in the light of data, or alternative structures (hypotheses) may be established or compared against the data. Each arrow connecting two variables is called "Path" and described in the form *"p"*. Each path has its own coefficient, which is usually described in the form of *"pji"*, where the subscript, *"j"*, refers to the dependent variable and "*i*", refer to the explanatory (or regressor) variable whose direct effect on the response is measured. Path coefficient, *"pji"*, explains the proportion of the standard deviation observed in the response variable, *"j"*, for which the explanatory variable, *"i"*, is directly responsible. The residual path (for extraneous variables) coefficient, *"PJE"*, measures the proportion of the standard deviation of *"j"*, which is explained by unmeasured extraneous variables, *"E"*.

Causal Path Diagram constructed by the author to measure the "professional training effects upon time overruns in Saudi construction projects" is presented in Figure 1.

Measurement of Variables

In order to statistically analyse the data using regression equations variables must be measured on a continuous interval scale. Mostly the techniques to measure the variables are developed by researchers themselves and it is an important part of research. Author used the following measurement techniques to measure the variables for his model.

Level of Training (LT): The level of training of the client's representative was measured on a likert scale, over a range, 1 to 5 (a value of, 1, being low and, 5, being high) against the following five principal training areas, maintaining the basic engineering, management and professional qualifications:-

(i) Value and risk management.
(ii) Contract and procurement.
(iii) Briefing.
(iv) Pre-qualifications and tender evaluation.
(v) Programming and project management.

The qualifications and experience of each client's representative included in the acquired data set were examined according to a predefined proforma considering the above criteria. In this way, a consistent interval measurement for each client's representative was obtained.

Risk: It was not possible to locate records of the estimated risk for projects that have been completed for

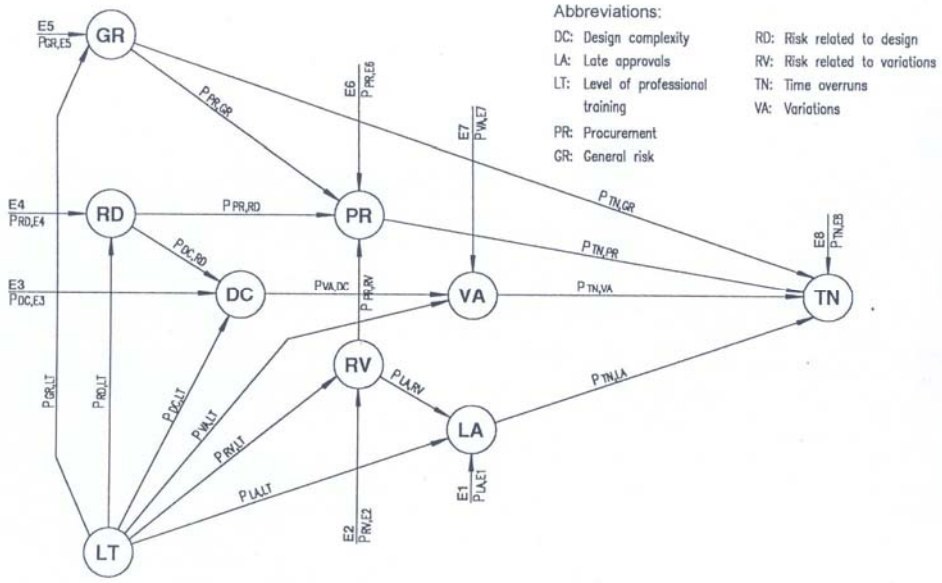

Figure 1: Amjad's Model

some time. Therefore it was necessary to construct a hybrid system to estimate the degree of risk present in each data set of project at the time of its original commencement. Such a system must result in a consistent risk measurement for each project. The measurement need only assess the risks in a given project relative to all the other projects in the data set.

A ranking system, consistently applied to all of the projects provided the most appropriate solution to the measurement problem. The ranking devised for this purpose examined six principal risk centres, namely:-

(i) Completeness of the project brief.
(ii) Design risk.
(iii) Contractual obligations.
(iv) Contractor (s).
(v) Supervising consultants.
(vi) Designer.

These risk centers were considered to contribute to the overall degree of risk present in a project at the time of its commencement. Again, a standard proforma was applied in the case of each project. A numerical weighting was assigned to each of the elements included in each risk centre. To obtain each of the desired risk measurements, each risk centre was categorised, based on its relationship with:-

(i) Risk effecting design complexity (RD)
(ii) Risk effecting number of variations (RV)
(iii) Risk related to the selection of contractors, consultants & contractual obligations (GR).

Design Complexity (DC): Again, established literature offered little guidance concerning the measurement of design complexity. In this case a hybrid system, previously applied by Brown (1996), was implemented. This single measure represented three key factors already identified by Bennett (1992). Design / technical complexity is thus the product of Project Size (PS), Complexity (C), and Repetition (R).

i. **Project size** was a management issue (not concerned with monetary value). It was assessed by an arithmetic count the maximum number of tasks that must be executed simultaneously in the course of project delivery.
ii. **Project complexity** was measured by an arithmetic count of the number of distinct trades that were required to complete a project.
iii. **Repetition** was scored on an interval scale having a range of 0 (no repetition) to 4.0 (high repetition). The scoring system examined all of the standard elements included in BCIS standard elemental cost analyses.

The arithmetic sums of actual scores for all of the elements were subsequently expressed as a ratio of the total possible repetition. The value, R, was computed using:-

$$R = \{\Sigma Sa/(4n)\} \times 100 \quad \text{..... (1)}$$

Where: -
ΣSa = The sum of actual scores;
n = The number of applicable elements in a given project.

The value, n, was multiplied by 4.0 since that was the maximum possible score for each of the relevant elements. It followed that a high score represents a more straightforward project than a low score. Since the design complexity was being measured on an increasing scale, reciprocal of R was used to obtain a useful measure.

Summing up, the reasoning applied to design complexity gave us the following expression for its measurement:-

$$DC = PS \times PC \times (1 / R) \quad \text{..... (2)}$$

Where: -
DC = Design Complexity;
PS = Maximum number of tasks / activities required to be managed at any one time.
PC = The number of distinct trades required to deliver the project.
R = Repetition score.

Procurement: Given the established differentiation between procurement systems, it was treated as a multichotomous discrete variable. Once again, a scoring system was applied, based on the level of difficulty, as follows:-

(i) Traditional contract (lump sum) = 1.0
(ii) Traditional contract (re-measured) = 2.0
(iii) Design and build = 3.0
(iv) Construction management contract = 4.0
(v) Contracting management = 5.0

Late Approvals (LA): The number of late approvals of design drawings and materials during construction was measured by straightforward arithmetic count.

Variations (VA): Measuring the number of variations that occurred during the construction phase was relatively straightforward. An arithmetic count of the number of supervising consultant's instructions (SCI), which were issued during the course of a construction contract, provided a valid measurement.

Time Overruns (TN): Time Overruns was measured as the ratio between planned construction and actual construction duration, expressed as follows:-

$$TN = \frac{\text{Actual Construction Duration (Days)}}{\text{Planned Construction Duration (Days)}} - 1.0 \quad \text{.....(3)}$$

Data Acquisition

In order to operate a path model in construction research data should be carefully acquired by determining the sample size, through case studies.

The author's acquired data set included projects that have a monetary value of SR10 to 900 million. All of the projects were completed in the last ten years. The range of time overruns (quantified as above) was from 0.2317 to 2.1597. The type of buildings included in the sample was greatly varied including hospitals, offices, commercial centres, cultural centres and off shore facilities. Moreover, the client organisations were well distributed so as to remove bias. These characteristics were considered to make the acquired data set particularly suitable. The details of the acquired data are shown in Table -1.

Statistical Analysis

In a path model the acquired data set is statistically analysed using multi-variate regression equations. A computer analysis package "MINITAB (version- 12)" can be used to analyse the data set. In order to remove the typical constant, "a", from the linear equation,

($y = a + bx_1$ ……- bxn, to zero), the acquired data set has to be standardised before statistically analysing it. It has the effect, that the observed path coefficient obtained through multi-variate regression equation represents the standardised effects as opposed to the real effect. It follows that the larger the path coefficient, the greater is the real effect of a variable upon the dependent / response variable. Later on these standardised effects are converted to the original scales of measurement.

Figure 2 presents the author's model with standardised Path Coefficients derived from the acquired data set using multi-variate regression analysis. Two points must be noted in relation to the information presented in Figure 2. First, the path coefficient represents effects of a particular variable upon another after statistical control for the effects of variables present earlier in the particular causal chain. Second, the data was standardised prior to regression analysis in order to remove typical constants from the linear equations. It has the effect that the observed path coefficient represents the standardised effect as opposed to the real effect. It follows that the larger the path coefficient, the greater is the real effect of any variable upon the response variable.

Table 1: Data As Quantified For Analysis Using Proposed Path Model

Project	Variables								
	LT	GR	RD	RV	DC	PR	LA	VA	TN
1.	2.00	30	14	7	23.1757	2	56	702	2.1597
2.	1.50	26	12	9	5.9733	2	45	146	1.1482
3.	0.00	17	13	11	39.7826	1	42	80	0.2317
4.	1.00	14	11	11	30.0933	1	41	305	0.6000
5.	1.00	20	13	11	11.8675	1	64	55	0.3345
6.	1.00	26	12	8	3.3000	4	53	54	0.4893
7.	1.00	25	14	7	24.7501	4	47	289	0.5071
8.	1.00	24	15	7	11.3422	4	79	131	o.6715
9.	1.00	23	14	8	36.2327	4	53	688	0.4131
10.	1.00	22	14	6	2.3040	4	63	368	0.0628
11.	0.50	22	9	11	45.3034	4	72	951	0.8869
12.	1.50	12	12	10	32.0493	1	55	435	0.5761
13.	0.00	20	10	11	37.7207	1	59	123	0.7892
14.	1.50	25	10	11	16.9069	1	54	45	0.5547
15.	0.00	18	12	11	43.6600	3	124	843	0.4022
16.	1.00	18	13	9	22.5800	1	57	367	0.9692

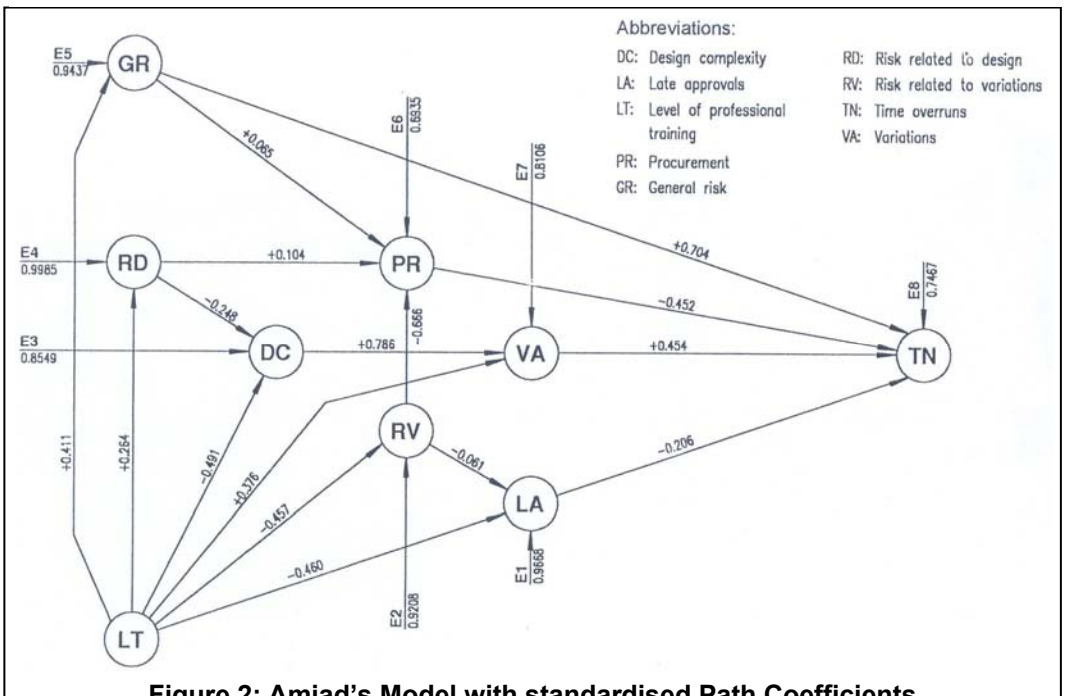

Figure 2: Amjad's Model with standardised Path Coefficients

Test of Statistical Significance

In order to evaluate the significance of a Causal Path Model the following statistical tests are normally carried out.

1. Test of goodness of fit with R^2.
2. The F ratio test of overall statistical significance.
3. Test of statistical significance for individual path coefficients known as "t" test.
4. Test of Multicollinearity

Test of Goodness of fit with R^2

The value, R^2 is known as the coefficient of determination and measures the proportion of variance that is explained by the regressor variables of the model. Calculating the value

1.0 - $R^{2,}$ produces the proportion of variance which is unexplained by the explanatory variables of the model (Retherford et al – 1993) and (Atkins, 1980).

Table 2 presents the results of test of goodness of fit with R^2 of author's model. As can be seen, the explained portion of variation in response variables for a number of equations is relatively small. Such results are not uncommon in management and social research (Atkins, 1980). In the regression analysis, 44.24% of variation observed in time overruns (TN) is explained by the variables GR, PR, LA & VA. This suggests that there is a good likelihood of a linear relationship between the regressor variables specified within the casual path model and the dependent variable of time overruns.

Table 2: Goodness of fit of model using R^2

Test of goodness of fit with R^2				
Regression Equation	**Response Variable**	**Regressor Variables**	**R^2**	**1.0 – R^2**
GR on LT	GR	LT	0.8906 89.06% of variation in GR not explained by the model	0.1094 10.94% of variation in GR explained by LT.
RD on LT	RD	LT	0.9970 99.70% of variation in RD not explained by the model	0.003 0.3% of variation in RD explained by LT.
RV on LT	RV	LT	0.8478 84.78% of variation in RV not explained by the model	0.1522 15.22% of variation in RV explained by LT.
DC on LT & RD	DC	LT & RD	0.7308 73.08% of variation in DC not explained by the model	0.2692 26.92% of variation in DC explained by LT & RD
PR on GR, RD & RV	PR	GR,RD, & RV,	0.4809 48.09% of variation in PR not explained by the model	0.5191 51.91% of variation in PR explained by GR, RD & RV
VA on LT, & DC	VA	LT, & DC	0.6570 65.70% of variation in VA not explained by the model	0.3430 34.30% of variation in VA explained by LT, & DC.
LA on LT, & RV	LA	LT, & RV	0.9347 93.47% of variation in LA not explained by the model	0.0653 6.53% of variation in LA explained by LT, & RV
TN on PR, GR,LA & VA	TN	PR,GR, LA, & VA	0.5576 55.76% of variation in TN not explained by the model	0.4424 44.24% of variation in TN explained by PR, GR, LA, &VA.

The F Ratio Test of Overall Statistical Significance

In path analysis F ratio tests the statistical significance of R^2, (goodness of fit). Furthermore it determines the significance of influence of explanatory and intervening variables upon dependent variables (Retherford et at – 1993) The value of F ratio depends on the quantum of variation observed by regressor variables in the response variables. If the regressor variables do not explain any of the variation observed in the response variables then the F ratio would be expected to approach zero. The more significant the relationship predicted by the regression, the higher the value of F. Therefore, in general, high values of the F ratio suggest significant relationships between regressor and response variables (Koutsoyiannous – 1977).

Table 3 presents the results of F ratio test for author's model. As can be seen, the regression equations for two important paths specified in the model are statistically significant at 95% confidence level. A further path is statistically significant at the 97.5% confidence interval. On lowering the confidence interval to 90 %, two more paths achieve statistical significance. These results infer that there is a good likelihood of linear relationships between the variables specified in the model.

Table 3: F Ratio Test for Statistical Significance of Regression Equations

F Ratio Test of Significance							
Regression	Observed F Ratio	Degrees of Freedom		From F Distribution Tables			Significant
		V1 (K- 1.0)	V2 (N-K)	F 0.90	F 0.95	F 0.975	
GR on LT	2.84	1	14	3.10	4.60	6.30	
RD on LT	1.05	1	14	3.10	4.60	6.30	
RV on LT	3.69	1	14	3.10	4.60	6.30	*
DC on LT & RD	3.76	2	13	2.76	3.81	4.97	*
PR on GR,RD & RV	6.40	3	12	2.61	3.49	4.47	* +x
VA on LT, & DC	4.91	2	13	2.76	3.81	4.97	* +
LA on LT,& RV	1.52	2	13	2.76	3.81	4.97	
TN on PR,GR,,LA, & VA	3.98	4	11	2.54	3.36	4.28	* +

* Significant at 90% Confidence Level
\+ Significant at 95% Confidence Level
x Significant at 97.5% Confidence Level

Test of Statistical Significance For Individual Path Coefficients Known As "t" Test

The "t" test examines the significance of each individual coefficients obtained for each of the specified causal path. Table 4 presents the results of "t" test for various confidence intervals.

Table 4: The Test for Statistical Significance of Path Coefficients

The t Test of Statistical Significance								
Path	Observed Coeffi-cient	Degrees of Freedom	Actual t ratio	From t Distribution Tables				Significant
				T 0.99 +/-	T 0.975 +/-	T 0.95 +/-	T 0.90 +/-	
PGR, LT	+ 0.411	14	+ 1.69	2.624	2.145	1.761	1.345	*
PRD, LT	+ 0.264	14	+ 1.02	2.624	2.145	1.761	1.345	
PRV, LT	- 0.457	14	- 1.92	2.624	2.145	1.761	1.345	* +
PDC, LT	- 0.491	13	- 2.15	2.650	2.160	1.771	1.350	* +
PDC,RD	- 0.248	13	- 1.08	2.650	2.160	1.771	1.350	
PPR,GR	+ 0.065	12	+ 0.28	2.681	2.179	1.782	1.356	
PPR,RD	+ 0.104	12	+ 0.36	2.681	2.179	1.782	1.356	
PPR,RV	- 0.666	12	- 1.96	2.681	2.179	1.782	1.356	* +
PVA, LT	+ 0.376	13	+ 1.49	2.650	2.160	1.771	1.350	
PVA, DC	+ 0.786	13	+ 3.12	2.650	2.160	1.771	1.350	* + x •
PLA, LT	- 0.460	13	- 1.64	2.650	2.160	1.771	1.350	*
PLA, RV	- 0.060	13	- 0.22	2.650	2.160	1.771	1.350	
PTN, PR	- 0.452	11	-1.97	2.718	2.201	1.796	1.363	* +
PTN, GR	+ 0.704	11	+ 3.13	2.718	2.201	1.796	1.363	* + x •
PTN, LA	- 0.206	11	- 0.91	2.718	2.201	1.796	1.363	
PTN, VA	+ 0.454	11	+ 2.10	2.718	2.201	1.796	1.363	* +

* Significant at the 90% Confidence level.
\+ Significant at the 95% Confidence level.
x Significant at the 97.5% Confidence level.
• Significant at the 99% Confidence level.

Test of Multicollinearity

In multiple regression it is always expected to find dependencies between the response and regressor variables and some times among regressor variables. In situations where these dependencies are strong, multicollinearity exists. Multicollinearity can have serious effects on the estimates of the regression coefficients and the general applicability of the model (Montgomery et al – 1999). Computer programs for regression analysis such as "MINITAB" automatically calculate the "variance inflation factors (VIF)" from the data set, which are very useful measures of multicollinearity. The larger the variance inflation factor, the more severe the multicollinearity. There is difference of opinion in accepting the degree of VIF for multicollinearity. Some researchers suggest that if the value of VIF exceeds 10, then the regression equation has a multicollinearity problem, whereas other consider this value to liberal and suggest that the variance inflation factors should not exceed 4 or 5 (Montgomery et al – 1999).

author's model. As can be seen, 2 paths ($P_{VA,DC}$, & $P_{TN,GR}$) are statistically significant at the 99% confidence level; 5 paths ($P_{RV,LT}$, $P_{DC,LT}$, $P_{TN,PR}$,$P_{PR,RV}$ & $P_{TN,VA}$) are statistically significant at the 95% confidence interval and 3 paths ($P_{GR,LT}$, $P_{VA,LT}$ & $P_{LA,LT}$) achieve significance when the confidence interval is lowered to the 90% level.

Figure 3 presents the author's model showing the statistically significant paths at the

Table 5: The Test of Multicollinearity

The Test of Multicollinearity								
Regression Equation	Degree of Freedom		Significance of F Ratio For Regression Equation		Individual Paths of Regression Equation			
	V1 (N-1.0)	V2 (N-K)	Observed F Ratio	Significant	Paths	Observed T Ratio	Significant	Observed VIF Ratio
GR on LT	1	14	2.84		GR on LT	+1.69	*	-
RD on LT	1	14	1.05		RD on LT	+1.02		-
RV on LT	1	14	3.69	*	RV on LT	-1.92	*+	-
DC on LT & RD	2	13	3.76	*	DC on LT	-2.15	*+	1.1
					DC on RD	-1.08		1.1
PR on GR,RD & RV	3	12	6.40	*+	PR on GR	+0.28		1.7
					PR on RD	+0.36		2.6
					PR on RV	-1.96	*+	3.6
VA on LT & DC	2	13	4.91	*+	VA on LT	+1.49	*	1.4
					VA on DC	+3.12	*+	1.4
LA on LT & RV	2	13	1.52		LA on LT	-1.64	*	1.3
					LA on RV	-0.22		1.3
TN on PR , GR,LA & VA	4	11	3.98	*+	TN on PR	-1.97	*+	1.4
					TN on GR	+3.13	*+	1.4
					TN on LA	-0.91		1.4
					TN on VA	+2.10	*+	1.3

* Significant at the 90% confidence level.
\+ Significant at the 95% confidence level.

Table 5 presents the results of multicollinearity of the model developed by author. The analysis confirms that the provisional model, as described, appears to be helpful in explaining the true nature of the relationships that exist between professional training and time overruns in Saudi construction project. To further check for linearity between regressor and response variables and to ratify the choice of the modelling approach taken, a number of standard procedures were carried out. Plots of residuals versus predicted values revealed no evidence that the assumed functional form (linearity) was incorrect and the Goldfield-Quandt test for the presence of heteroscedasticity proved null (see Johnston, 1984).

Results

Path statistically significant at 95% confidence interval or above are normally considered as "Significant Paths" for research. For example, author's model (Figure 3) shows that the level of professional training (LT) influences the time overruns (TN) at Saudi construction projects through the following two significant paths.

Path 1: LT→ RV → PR → TN
Path 2: LT→ DC → VA →TN

The rest of postulated six paths did not turn out to have statically significant effects. These are known as zero path coefficients. They are not significantly different from zero in statistical terms at least, despite their validity from a priori reasoning.

Path Coefficients Not Significantly Different From Zero

Observation of insignificant paths is not uncommon in causal modelling and researchers often encounter the above situation; e.g, Brown's (1996) model distinguished nine such paths. Atkins (1980) says that it is not possible to know the exact reason, however, possible explanations include:

1. Variables of insignificant paths have no direct influence upon one another, and they act in an unspecified way through another intervening variable not included in the model.
2. Variables of insignificant paths are alternative indicators of the same concept, already included in the model. In the case of author's model, the method of measurement of the variable adopted ruled out the occurrence of such situation. In order completely to rule out this possibility, correlation among explanatory variables was re-examined and none was close to 1.0. Hence, this possibility is completely ruled out in author's model.
3. The final reason for finding an insignificant path is known as spurious correlation. In this case an

explanatory variable does not cause any change in the dependent variable, either directly or indirectly. The spurious correlation between variables may arise in three ways:

a. By chance in the particular data set being analysed.
b. If both the variables depend on some other unspecified variables.
c. If an explanatory variable is in fact caused by another explanatory variable.

In each of these cases an explanatory variable does not cause any change in a dependent variable but is correlated with it. The true interpretation of zero path coefficients is simple, that an explanatory variable does not cause any change in a dependent variable and hence no causal relationship exists between them. In the case of author's model, most likely it is considered that the six numbers of insignificant paths observed fall in this category.

Total Effect

Total effect of each "significant path" can be calculated by multiplying the path coefficients. These standard units are converted back to original scales. The total effect of two significant paths of author's model was determined as follows.

Total effect of professional training level upon time overruns through Path No. 1:

Effect of LT upon TN through RV and PR @ 95%
$= (P_{RV, LT} \times P_{PR, RV} \times P_{TP, PR})$
$= (- 0.457) \times (- 0.666) \times (-0.452)$
$=$ **(- 0.1376)**

This means that the current training level through procurement reduces the extent of time overruns by – 0.1376 standard units or 10.90% as converted back to original scales in Table 6.

Total effect of professional training level upon time overruns through Path No. 2:

Effect of LT upon TN through DC and VA @ 95%
$= (P_{DC, LT} \times P_{VA, DC} \times P_{TN, VA})$
$= (-0.491) \times (+ 0.786) \times (+ 0.454)$
$=$ **(- 0.1752)**

This means that the current training level through design complexity and variations decreases the extent of time overruns by – 0.1752 standard units or 13.86% as converted back to original scales in Table 7.

Overall effect of training level upon time overruns:

Overall effect of current training level upon time overruns through two different causal paths as calculated above would be as follows:-

Effect through Path No. 1	= (- 0.1376)
Effect through Path No. 2	= (- 0.1752)
Total effect	**= (- 0.3128)**

This means that each unit of professional training level (LT) of the client's representatives, decreases the extent of time overruns for Saudi construction projects through intervening variables; risk (RV), procurement (PR), design complexity (DC) and variations (VA) by 0.3128 standard units or 24.76% on original scales

Interpretation of Results

In a path analysis it is more important to know that how to interpret coefficients produced by a computer program or reported in other people's research. Mostly the results are interpreted through the signs of correlations and postulated hypotheses in order to find the answers of research questions.

The results of author's path analysis establish a significant negative correlation (relationship) between the level of training, the number of late approvals, the risk of variation, and design complexity. The results suggest a strong likelihood of an inversely proportional relationship. It follows that increasing training would result in reduction in errors in design & tender documents, and in projects design complexity.

A further reductionary influence of training on time overruns can be seen; this is transmitted via the selected procurement

Table 6: Actual Effect of the Professional Training upon Time Overruns Through Path No.1

Path	PRV, LT	PPR, RV	PTN, PR	Total
Standard Effect (SE)	-0.457	-0.666	-0.452	
Standard Deviation of Regressor. (SX)	0.57373	1.8439	1.3769	
Standard Deviation of Response. (SY)	1.8439	1.3769	0.45484	
SY/SX	3.2139	0.7467	0.3303	
Real Effect (SY/SX) SE	-1.4688.	-0.4973	-0.1493	-0.1090 Or -10.90%

Table 7: Actual Effect of the Professional Training upon Time Overruns For Path No. 2

Path	PDC, LT	PVA, DC	PTN, VA	Total
Standard Effect (SE)	-0.491	0.786	0.454	
Standard Deviation of Regressor. (SX)	0.57373	14.408	298.62	
Standard Deviation of Response. (SY)	14.408	298.62	0.45484	
SY/SX	25.11286	20.72599	0.00152	
Real Effect (SY/SX) SE	-12.3304	16.2906	0.00069	-0.1386 Or -13.86%

system and the extent of authorised variations. Again, it follows that an increase in training would result in the selection of a more appropriate procurement system, given the circumstances of a particular project, and in the more careful monitoring and suppression of variation orders. This second point may be an alternative indicator highlighting that the design brief and the finished design complexity may be improved with one another in the case where the client's representative is more highly skilled, or (in view of the fundamental characteristics of the Saudi construction industry) that the more competent client's representative advises their client more forcefully of the consequences of alterations during construction and therefore averts the variation order.

In short, the model suggests a 24.76% reduction, in the extent of time overrun for each extra ranking point that an individual earns on the training interval scale. The scale of this influence is unexpectedly large and suggests that the benefits of improved professional training, in the Saudi construction industry, may be much greater than originally anticipated.

Limitations of Causal Models

The causal path analysis method has a number of limitations. Firstly, there is no guarantee that the causal relationship observed by the model will continue to operate in future instances, since the path coefficients are considered as retrospective and they explain the system of variable as it is observed. Secondly, in practice, it is extremely difficult to rule out the possibility of circular causation and interactions between variables. However, these difficulties are not particular with the casual path analysis method, and Little (1979) states that such difficulties exist in any analysis which is of a cross sectional nature. Regression equations allow for prediction however uncertainty from data must be removed before forecasting (Kazmier, 1996) Therefore, while using the causal path models the above limitations have to be properly considered as far as possible.

Path Models and Policy Decisions

Once the researcher is satisfied that the model is theoretically sound and fits the data adequately, it can be used to discuss the effects of various hypothetical manipulations of the variables which are policy or theoretical interest. By tracing influences along the causal paths researcher can examine the effect of alternative policies on any of the dependent variables in the model.

For example, using author's model authorities in Saudi Arabia can determine and compare the cost of professional training versus improvement in time delivery of construction projects for different standard units of professional training (of client representative) in the identified areas (see Amjad 2003) for policy decisions.

Conclusion

The causal modelling provides robust analytical framework within which the strength of influences between variables can be measured and understood. The unique feature of causal modelling is to present the theoretical assumptions and research hypotheses in a path diagram, which is easier to understand. Path diagrams are often used to discuss the effects of various hypothetical manipulations of the variables which are of policy or theoretical interest. However, like other statistical models there are limitations that must be observed while developing causal models.

Use of causal modelling in construction research is still at earlier stage and the available both models are of provisional nature, since the data limitation and to minimise complexity, many variables that could have been included from a theoretical perspective, remained extraneous. Nevertheless, one of these provisional models (author's model) confirms the hypothesis and suggests a high probability of strong linear relationships among a set of variables. Hence, a more developed model examining a greater number of variables could be expected to enhance the author's understanding; however, the scale of relationship that is indicated by the provisional model is larger than originally anticipated and is indicative of the need for further research in this area. Indeed, it would be interesting that though much research has previously investigated training as a cause of delay, little has been done to model the nature of influences that exist between the level of professional training of an individual project executive and project performance. Therefore pilot programmes and action research present an interesting avenue to further the work.

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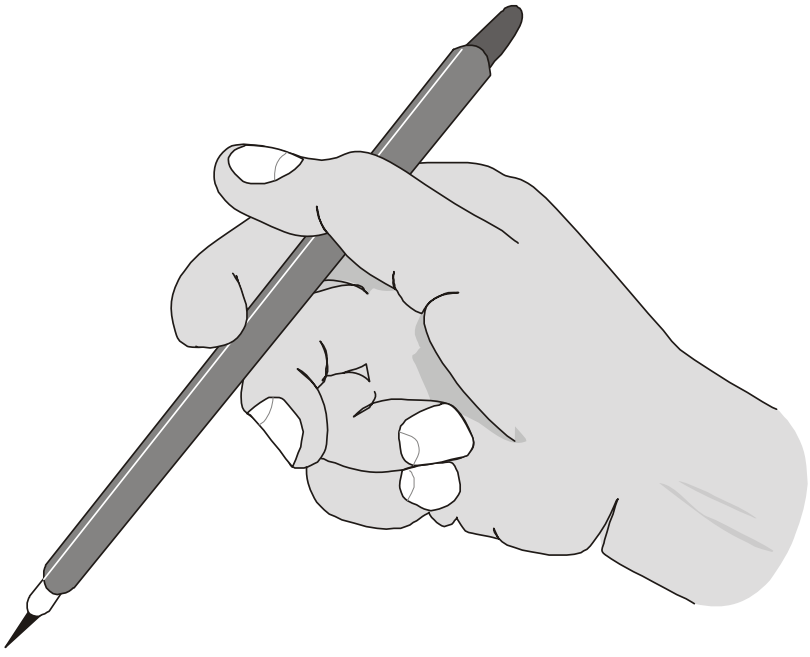

DIRECTORY OF PAKISTANI ENGINEERS IN THE KINGDOM OF SAUDI ARABIA

ALPHABETICAL INDEX

NAME	DISCIPLINE	PH. (OFFICE)
ABDUL ALI SIDDIQUI	Chemical	(01) 285-1867
ABDUL AZIZ SAQIB	Miscellaneous	(01) 476-9777 x 40556
ABDUL BASIT AMJAD	Civil	(03) 330-6666 x 75120
ABDUL GHAFOOR	Electrical	(01) 464-3333 x 4868
ABDUL GHAFOOR KHAN	Electrical	(01) 464-1188
ABDUL HAFEEZ ANJUM	Electrical	(03) 362-1824 x 76580
ABDUL HAFEEZ MUGHAL	Electrical	(01) 476-7407 x 2257
ABDUL HAMEED	Chemical	(03) 340-1662
ABDUL HANNAN	Electrical	(01) 495-5332 x 124
ABDUL JALAL	Electrical	(01) 402-6809
ABDUL MAJEED KALAIR	Electrical	(03) 895-5004 x 426
ABDUL MAJID KHAN	Electrical	(03) 864-9612
ABDUL MATEEN AZMI	Mechanical	(03) 857-4082
ABDUL MUQEET	Electronics	(01) 403-2222 x 1345
ABDUL QADIR AKBANI	Mechanical	(03) 857-4150
ABDUL QAYYUM	Electrical	(01) 462-2011 / 465-6613
ABDUL QAYYUM QURESHI	Electrical	(03) 843-3404
ABDUL QUDDUS	Mechanical	(03) 860-3533
ABDUL QUDDUS M.	Mechanical	(01) 464-3333 x 4803
ABDUL RAHMAN LALDIN	Electrical	(01) 461-9274
ABDUL RAUF	Electrical	(01) 478-5448
ABDUL REHMAN	Chemical	(01) 477-9111 x 322
ABDUL SATTAR	Electrical	(01) 239-7320
ABDUL WAHEED	Mechanical	(03) 857-2300 x 84979
ABDUL WAHEED KHAN	Civil	(01) 477-7222 x 168
ABDUL WAHEED MIR	Electrical	(01) 403-2222 x 14546
ABDUR RASHID HAQ	Civil	(02) 622-4444 x 580
ABDUR RASHID SHAD	Civil	(01) 474-0111 x 218
ABID WASEEM ASLAM	Civil	(01) 476-8118
ABID ZAMAN KHAN	Mechanical	(01) 478-9000 x 4610
ADEEL BIN AFZAL	Electrical	(01) 293-5661
AFAQ HUSSAIN SIDDIQI	Civil	(01) 403-7878 x 430
AFTAB AHMAD MALIK	Mechanical	(03) 882-6666 x 2806
AFTAB AHMED	Civil	(02) 667-0500 x 117
AFTAB ALAM	Civil	(02) 542-6421
AFTAB NASEER	Civil	(01) 464-1498
AFZAAL SHAIQ QADRI	Chemical	(01) 523-1489
AGHA ZIA-UL-HASSAH	Mechanical	(01) 465-4235 x 105
AHMAD NADEEM	Electrical	(03) 847-3020
AHMAD SOHAIL SIDDIQUI	Electrical	(01) 452-8896
AHMAD WARAICH	Civil	(01) 454-9191 x 245/267
AHSAN AHMED RANA	Electronics	(01) 452-6239
AHSAN ALI LOONA	Mechanical	(01) 476-8686 x 108
AHTSHAM AHMED	Mechanical	(02) 550-6273 x 330
AKHTAR JAWAID NIAZI	Civil	(03) 832-6402
ALEEM PIRACHA	Electronics	(03) 358-4744 x 8981
ALI AKBAR	Electrical	(01) 465-6150
ALTAF HUSSAIN KHAN	Electrical	(01) 465-9975 x 206
AMIR BIN RAUF	Mechanical	(03) 357-7276
AMJAD RASHEED	Electrical	(01) 275-5999 x 815
ANIS AL-HASAN	Civil	(02) 667-6612
ANIS UR REHMAN KHAN	Civil	(03) 864-2642
ANJUM K. ALVI	Mechanical	(03) 343-0333 x 30719
ANJUM SAEED	Civil	
ANWAR KHALIL SHEIKH	Mechanical	(03) 860-2575
ANWAR NAZAR ALI	Electrical	(01) 465-2260 / 463-3417
ANWAR RAZA KHAN	Mechanical	(03) 340-1627
ANWAR UL HAQ	Civil	(01) 485-4644
AQIL NASIR MIRZA	Electrical	(03) 357-7603
ARIF HABIB	Electrical	(03) 864-0091
ARIF ISLAM BUTT	Electronics	(02) 651-9998 x 231
ARSHAD ALI	Electrical	(07) 227-1111 x 1328
ARSHAD ALI AMJAD, DR.	Civil	
ARSHAD HUSSAIN	Electronics	(01) 493-6622 x 260
ARSHAD HUSSAIN	Civil	(01) 243-0359
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ARSHAD M. CHOHAN	Architecture	(02) 675-7253
ARSHED ALI	Electrical	(01) 477-6666 x 6169
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ASAD NAVEED	Electrical	(03) 860-4069
ASADULLAH ABDUL	Electrical	(01) 265-3030 x 1423
ASHFAQ MOHAMMAD	Architecture	(01) 464-1188 x 207
ASIF ABBAS ZAIDI	Mechanical	
ASIF MAJEED	Electrical	(01) 245-2434
ASIF MAQSOOD SHEIKH	Mechanical	(01) 477-5192
ASIF RASUL	Electrical	(01) 435-5125 x 1868
ASIF ZAFAR	Mechanical	
ASRAR KHAN GHORI	Civil	(01) 465-8665 x 258
ASRAR M AHMED	Civil	(02) 542-6421
ASRARUL HAQ SHEIKH	Electrical	(03) 860-1182
ATA UR RAHMAN	Civil	(04) 392-5316
ATEEQ UR REHMAN	Metallurgy	
ATHAR ALIM KHAN	Mechanical	(01) 488-2226 x 23
ATHER JAMIL DAR	Electrical	(01) 452-8847
AZHAR I. KHAN	Electrical	(02) 665-8420
AZIMUDDIN QURESHI	Electrical	(02) 653-1765 x 233
AZIZ AKHTAR CHOUDERY	Electrical	(01) 464-3333 x 14864
AZIZ ARSHAD	Miscellaneous	(03) 860-2761
AZIZ UR RAHMAN	Civil	(01) 478-0574
AZIZ ZARULLAH KHAN	Metallurgy	(03) 830-2396
BABAR SULTAN	Civil	(03) 889-1576 x 14
BADAR UZ ZAMAN	Mechanical	(03) 357-5757
BASHIR AHMAD MALIK	Electrical	(01) 452-1764
BAZURJ MEHR KHAN	Electrical	(01) 442-2000 x 360
BILAL AKHTAR	Electrical	(03) 882-5669 x 244
CHAUDHARY GULRAIZ	Civil	(01) 211-0087
CHAUDHARY M. SHARIF	Electrical	(01) 464-3333 x 14354
CHAUDHARY	Mechanical	(03) 357-8805
CHAUDHARY	Electrical	(01) 477-9111 x 155
CHAUDHARY RIAZ	Computer	(03) 860-2139
CHAUDHARY SARFARAZ	Electrical	(03) 860-2134
DEEDAR ALI	Electronics	(01) 452-9187
DIWAN Y. DAWOOD	Electrical	(03) 673-2833
EBRAR AHMED SHAMS	Civil	(03) 586-2144
EHSANUL HAQUE	Electrical	(02) 639-0172
EHSAN-UL-HAQUE	Electrical	(01) 246-2776 x 36
ENAYAT-ULLAH KHAN	Electrical	(01) 442-2000 x 312
FAHAD KARIM KHAN	Electrical	(03) 857-2537
FAHEEM ELAHI ANSARI	Chemical	(02) 686-4288
FAISAL MALIK	Mechanical	(01) 491-1333 x 385
FAQIR HUSSAIN	Civil	(03) 812-2967
FAREED AHMED	Mechanical	(01) 491-1333

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NAME	DISCIPLINE	PH. (OFFICE)
FAREED AHMED MEMON	Electrical	(07) 227-1111 x 1493
FAREEDUDDIN AHMED	Electronics	(03) 860-2884
FARHAT ALI BURNEY, DR	Mechanical	(02) 695-2251
FAROOQ AHMED BHATTI	Architecture	(03) 895-5004 x 412
FAROOQ AHMED	Electrical	(01) 498-3844
FAROOQ HAMEED	Mechanical	(03) 357-7332
FAROOQ SALEEM IKRAM	Chemical	(03) 340-6663
FASIH AHMED	Civil	(01) 482-3380 / 482-3258
FASIH-UZ-ZAMAN KHAN	Mechanical	(01) 476-3030 x 295
FATEH KHAN	Electrical	(01) 241-2228 x 4126
FAYYAZ AHMED KHAN	Mechanical	(01) 476-3030 x 283
FAYYAZ MUDDASSIR	Mechanical	(03) 343-0333 x 38503
FAZAL-UR-REHMAN AWAN	Metallurgy	(03) 359-9230
GHAZANFAR ALI IQBAL	Electrical	(03) 858-6636
GHUFRAN AHMED	Electrical	(03) 882-5669 x 240
GHULAM ABBAS	Electrical	(01) 405-5143
GHULAM HUSSAIN KHAN	Mechanical	(01) 467-6841
GHULAM RASUL	Electrical	(04) 882-1289
GHULAM SAFDAR	Civil	(01) 226-3727
GHULAM SARWAR	Mechanical	(01) 464-1188
HABIB UR REHMAN	Civil	(03) 893-8495 / 894-9704
HABIBULLAH TALPUR	Mechanical	(01) 241-4364 x 4220
HAFEEZ-UR-REHMAN	Electronics	(01) 472-5000
HAFIZ KHADIM HUSSAIN	Civil	(01) 477-3115 x 5244
HAFIZ MUHAMMAD	Mechanical	(02) 651-9998 x 233
HAMID ALI	Electrical	(03) 586-8600 x 2627
HAMID ALI KHAN	Civil	(01) 454-9191 x 239
HAMID MOHSIN	Electrical	(01) 479-3000
HAMIDUR RAHMAN	Electrical	(01) 478-0320
HASSAN SIDDIQUI	Electrical	(01) 291-2877 x 243
HUMAYUN AKHTAR	Electrical	(01) 443-1570
HUSAIN AHMED	Electrical	(03) 378-5510
IFTIKHAR AHMAD QAZI	Chemical	(01) 285-1889
IFTIKHAR AHMED	Electrical	(01) 404-0910
IFTIKHAR AHMED HAJI	Electronics	(01) 452-8184
IFTIKHAR NADEEM	Miscellaneous	(03) 860-3893
IJAZ AHMAD KHAN	Civil	(01) 465-9975 x 115
IJAZ HUSSAIN	Electrical	(01) 472-4473
IKRAM HUSSAIN	Chemical	(03) 860-3085
IMRAN ASHRAF	Electronics	(01) 462-8562 x 141
IMRAN IDREES MEMON	Electrical	(01) 265-3030 x 1592
IMRAN IJAZ	Mechanical	(03) 895-5004 x 145
IMRAN SULTAN	Mechanical	(03) 857-7710
IMTIAZ AHMED	Civil	(01) 295-3015
IMTIAZ AHMED DURRANI	Civil	(02) 671-5621
IMTIAZ KHALID	Electrical	(01) 465-5610
INAM KHAN	Electrical	(03) 842-2442
INAM MUHAMMAD	Mechanical	(03) 860-2520
INAYAT ULLAH MEMON	Electrical	(03) 678-8288 x 1071
IQBAL AHMED	Electrical	(01) 478-2027 x 35
IQBAL AHMED KHAN	Mechanical	(03) 677-1104
IQBAL AHMED SIDDIQUI	Electronics	(01) 491-1139 x 2239
IQBAL HAIDER MALIK	Mechanical	(01) 403-2222 x 1372
IQBAL HUSSAIN	Civil	(01) 478-1444 / 477-8309
IQBAL ISMAIL KHURRAM	Electrical	(01) 239-7497
IRFAN AHMED CHISHTI	Civil	(04) 322-8636
IRFAN ALI KHAN	Mechanical	(01) 474-5296
IRFAN BROHI	Mechanical	(03) 857-3559
IRFAN ELAHI	Mechanical	(03) 341-5939 / 03-
IRSHAD AHMED	Mechanical	(07) 227-1111 x 1615
IRSHAD NABI	Civil	(01) 465-6975
ISLAM AHMAD ASIF	Electrical	(03) 889-1609 x 1576
ISLAM MUSHEER KHAN	Mechanical	(03) 854-2058
ISMET AMIN KHAWAJA	Civil	(03) 864-6593
ISRAR UL HAQ	Electrical	(01) 246-6500 x 235
ISRAR ULLAH KHAN	Civil	(03) 357-5062
JALEEL HASAN	Electrical	(01) 217-9011
JAMAL NISAR KHAN	Electrical	(02) 669-6909 x 185
JAMIL A. WARSI	Mechanical	(01) 463-3330
JAMSHED MUSTAFA	Computer	(01) 467-5147
JAVAID HAMEED	Electrical	(03) 858-6350
JAVAID IQBAL	Civil	
JAVED IQBAL	Civil	(03) 865-6982
JAVED M. AHSANI	Electronics	(01) 460-0590
JAVED NADEEM	Electrical	(03) 882-9546
JAVED SAFDAR	Electrical	(03) 858-6747
JAVED SHAMIM	Electrical	(01) 452-7928
JAWAID INAM	Electrical	(03) 864-8371
JAWAID IQBAL	Mechanical	(02) 654-5683 / 692-0422
JAWED ANWER	Miscellaneous	(03) 872-8374
JAWED IQBAL	Civil	(01) 419-1818
JUNAID AHMAD HASHMI	Electrical	(01) 401-4806
KAFEEL AMEEN KHAWAJA	Miscellaneous	(03) 864-6593
KAMRAN ASIF ASLAM	Electronics	(01) 473-1300 x 107
KARAMAT ULLAH	Electrical	(03) 361-0333 x 30774
KAUSER MAHMOOD BUTT	Electrical	(01) 403-2222 x 23196
KAWISH ABBASI	Civil	
KHALID ALI	Mechanical	(07) 227-1111 x 1358
KHALID HABIBULLAH	Electronics	(01) 403-2222 x 1329
KHALID HUSSAIN KHAN	Electrical	(03) 812-1155
KHALID IQBAL WARRAICH	Architecture	(01) 240-6483
KHALID LATIF	Mechanical	(03) 357-7609
KHALID MAHMOOD DR.	Civil	(02) 695-2250
KHALID MAHMOOD MALIK	Civil	(01) 476-3030
KHALID MASOOD BARLAS	Mechanical	(01) 476-6500
KHALID NADEEM	Electronics	(02) 650-4744 x 478
KHALIL AHMED	Computer	(01) 477-6777 x 3417
KHALIL UR REHMAN SHAH	Mechanical	(01) 442-7686
KHAWAJA GHULAM	Mechanical	
KHAWAR IQBAL KHAN	Mechanical	(02) 531-7420
KHIZAR JUNAID USMANI	Electrical	(01) 265-3030 x 1562
KHURRAM KARAMAT	Civil	(01) 465-9975 x 107
KHURRAM SHAHID	Computer	(01) 478-1212 x 227
KIRMANI SYED	Civil	(01) 465-3127
KUNWAR MUHAMMAD	Electrical	(02) 672-9913
LAIQUE HAIDER	Civil	(03) 862-5481
LIAQAT ALI KHAN	Electrical	(03) 586-8600 x 62739
LIAQAT ALI SAHI	Mechanical	(03) 873-8959
M. ASHRAF KHAN	Electrical	(01) 265-1515 x 626
M. FARAZ UDDIN	Electronics	(01) 452-7808
M. FEROZE SAYEED	Mechanical	(03) 834-4500 x 603
M. IMRAN ASGHAR	Mechanical	(03) 3575709

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NAME	DISCIPLINE	PH. (OFFICE)
M. IRSHAD A. USMANI	Electrical	(03) 843-1874
M. JAVED AKHTAR	Electrical	(03) 895-5004
M. JAVED IQBAL	Electrical	(03) 889-1609
M. SHABBIR SHEKHANI	Electrical	(03) 882-1111 x 5050
M. WAHEED CHUGHTAI	Civil	(01) 239-7619
M.J.K. ZARRAR SHARIF	Mechanical	(01) 435-8422 x 1686
MAHMOOD SARWAR	Electrical	(01) 464-3333 x 14573
MAHMOOD USMAN	Electrical	(07) 227-1111 x 1128
MAHMOOD-AL-HASSAN	Electronics	(03) 343-0333 x 39300
MAJID LATIF	Electronics	(01) 476-3777 x 141
MAJOR WAHID AHMED	Civil	(01) 260-0087
MALIK HUMAYOON IQBAL	Civil	(01) 478-9000 x 4635
MALIK ZUBAIR	Electronics	(03) 887-0188 x 253
MAQBOOL AHMED BHATTI	Mechanical	(01) 419-6425
MAQBOOL HUSSAIN	Miscellaneous	(01) 465-9975 x 249
MAQBUL AHMED	Mechanical	
MAQSOOD ALAM	Electrical	(01) 265-0515
MAQSOOD HAMID	Chemical	(03) 357-7220
MAQSOOD HUSSAIN	Electrical	(02) 667-0500
MAROOF AHMED JAFFERI	Mechanical	(03) 858-0511 x 216
MASOOD ELAHI	Mechanical	(01) 251-3559 / 251-3465
MASOOD HAMID	Electrical	(02) 697-2620 / 697-6958
MASOOD SAID	Mechanical	(02) 663-5666
MASOOR AHSAN	Electrical	(02) 686-4855
MASROOR AKBAR RAMZI	Electrical	(01) 403-2222 x 23150
MASUD KHAN	Electrical	
MASUD UL HASAN	Electrical	(03) 860-2362
MAZHAR NAWAZ KHAN	Electrical	(03) 835-8807
MAZHAR NOOR	Electrical	(01) 206-0000 x 3326
MEHZAD SAHAR	Electrical	(03) 872-8586
MIAN FAHEEM-UL-GHANI	Electronics	
MIAN SHAMIM AHMAD	Mechanical	(01) 464-1188 / 488-4722
MIR MAJID TAUSEEF	Electrical	(01) 464-3333 x 14317
MIR SARFARAZ ALI KHAN	Civil	(03) 895-5004 x 465
MIR ZAMAN KHAN	Mechanical	(02) 654-7171
MIRZA AHTESHAM UD DIN	Civil	(02) 667-2082
MIRZA ZAMIR AHMED	Electrical	(01) 275-5999 x 806
MOBASHIR AHMED	Electrical	(02) 663-4442
MOHAMMAD ABBAS	Mechanical	(03) 341-0109 x 3517
MOHAMMAD ABDUL	Electrical	(03) 832-4400 x 148
MOHAMMAD ABDUL	Civil	(03) 858-6629
MOHAMMAD ABDULLAH	Electrical	(03) 895-5004 x 150
MOHAMMAD ABRAR	Electrical	(07) 227-1111 x 1328
MOHAMMAD ADIL	Civil	(03) 847-1500 x 1502
MOHAMMAD AFTAB	Electrical	(01) 495-1300 x 659
MOHAMMAD AFZAL	Electrical	(03) 857-9126 x 3536
MOHAMMAD AFZAL	Civil	(03) 341-3096
MOHAMMAD AFZAL	Civil	(03) 859-1999
MOHAMMAD AFZAL	Electrical	(03) 894-3025
MOHAMMAD AJMAL KHAN	Electrical	(01) 477-6777 x 1553
MOHAMMAD AKHTAR	Electrical	(03) 858-6516 x 86516
MOHAMMAD AKRAM	Electrical	(01) 476-9777 x 42550
MOHAMMAD AKRAM	Electrical	(03) 341-4276
MOHAMMAD ALIUDDIN	Civil	(03) 766-0055 x 4079
MOHAMMAD AMIN	Electrical	(03) 533-2222 x 1202 /
MOHAMMAD AMIN UDDIN	Electrical	(03) 833-7110
MOHAMMAD AMON KHAN	Electrical	(03) 678-8465
MOHAMMAD ANWAR	Civil	(02) 631-2280 x 514
MOHAMMAD ANWAR	Mechanical	(01) 477-6777 x 1371
MOHAMMAD ANWAR	Civil	(03) 883-2377
MOHAMMAD ARIF	Mechanical	(01) 245-3681 x 9751
MOHAMMAD ARSHAD	Mechanical	(01) 464-3500 x 450
MOHAMMAD ARSHED	Electrical	(01) 403-2222 x 23199
MOHAMMAD ARSHED	Mechanical	(07) 227-1111 x 1358
MOHAMMAD ASGHAR	Mechanical	(03) 341-7658
MOHAMMAD ASGHAR	Mechanical	(03) 357-7084
MOHAMMAD ASHFAQ	Electrical	(01) 265-0515 / 406-6669
MOHAMMAD ASHRAF	Electrical	
MOHAMMAD ASHRAF	Electrical	(03) 857-2300 x 84502
MOHAMMAD ASHRAF	Electrical	(01) 467-6692
MOHAMMAD ASIF	Electrical	(01) 293-3831 x 125
MOHAMMAD ASLAM	Electrical	(01) 464-1498
MOHAMMAD ASLAM	Electrical	(01) 291-2000 x 415
MOHAMMAD ASLAM	Miscellaneous	(03) 889-1609
MOHAMMAD ASLAM	Electrical	(03) 895-5004 x 425
MOHAMMAD ASLAM KHAN	Electrical	(01) 498-0391 x 18
MOHAMMAD ASLAM	Mechanical	(03) 341-0671 x 246
MOHAMMAD ATIQULLAH	Electrical	(03) 894-6816
MOHAMMAD AWAIS	Electrical	(03) 363-1824 x 76585
MOHAMMAD AYAZ QUTUB	Electrical	(01) 408-6630
MOHAMMAD AYOUB WALI	Metallurgy	(03) 817-5133
MOHAMMAD AZAM	Electrical	(02) 574-9045 x 404
MOHAMMAD AZAM	Electrical	
MOHAMMAD FAHEEM	Civil	(03) 812-2967 x 239
MOHAMMAD FAHEEM	Mechanical	(03) 340-8881/2
MOHAMMAD FAHIM	Civil	
MOHAMMAD FAWAD	Civil	(01) 464-9835 / 462-3955
MOHAMMAD FAWAD	Electronics	(01) 492-6818
MOHAMMAD FAZLUL AMIN	Mechanical	(01) 245-3681 x 9335
MOHAMMAD FEROZE	Mechanical	(03) 894-6816 x 255
MOHAMMAD HAFEEZ-UR-	Electrical	(03) 341-4223
MOHAMMAD HANIF	Electronics	(01) 265-3030 x 1371
MOHAMMAD HAROON	Electrical	(03) 341-0109
MOHAMMAD HASAN	Civil	(03) 891-2838
MOHAMMAD HASEEB NAZ	Computer	(01) 230-3111 x 2003
MOHAMMAD HASSAN	Electrical	(01) 462-9995
MOHAMMAD HUSSAIN	Electrical	(01) 458-2222 x 3502
MOHAMMAD HUSSAIN	Mechanical	(03) 857-7710
MOHAMMAD IBRAHIM	Civil	(01) 478-9000
MOHAMMAD IDREES	Electrical	(03) 231-2222 x 3742
MOHAMMAD IDREES	Electrical	(01) 403-2222 x 23243
MOHAMMAD IFTEKHAR-	Civil	(01) 464-9688
MOHAMMAD IFTIKHAR	Metallurgy	(03) 864-4111
MOHAMMAD ILYAS	Electrical	(02) 671-4774
MOHAMMAD ILYAS	Electrical	(01) 452-7664
MOHAMMAD ILYAS SHAH	Civil	(03) 889-1609
MOHAMMAD IMAMUDDIN	Electronics	(03) 857-2595
MOHAMMAD IMRAN	Electrical	(03) 899-1930
MOHAMMAD IMTAR	Electrical	(03) 857-7000
MOHAMMAD IQBAL	Mechanical	(02) 669-5851
MOHAMMAD IQBAL	Electrical	(02) 684-1693
MOHAMMAD IQBAL	Electrical	(01) 467-6963

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NAME	DISCIPLINE	PH. (OFFICE)
MOHAMMAD IQBAL	Electronics	(01) 467-6069
MOHAMMAD IQBAL	Electrical	(01) 452-9362
MOHAMMAD IRFAN	Electronics	(07) 227-1111 x 1128
MOHAMMAD ISHAQUE	Mechanical	(01) 221-2067
MOHAMMAD ISHTIAQ	Electrical	(03) 341-7493
MOHAMMAD ISRARUL	Mechanical	(03) 858-6529
MOHAMMAD JAFAR KHAN	Civil	(03) 897-1050
MOHAMMAD JAMSHAID	Mechanical	(03) 574-4134
MOHAMMAD JASIM	Civil	(01) 252-0088 x 4559
MOHAMMAD JAVAID	Electrical	(01) 468-3031
MOHAMMAD JAWAID	Electrical	(02) 682-7337
MOHAMMAD KALIMUR	Civil	(03) 860-1129
MOHAMMAD KASSIM	Electrical	(01) 265-3030 x 1337
MOHAMMAD KHALID	Electrical	(02) 682-7337
MOHAMMAD KHALID	Electrical	(03) 895-5004 x 322
MOHAMMAD KHURSHID	Civil	(01) 464-9688
MOHAMMAD MAHFOOZ	Civil	(01) 241-6111
MOHAMMAD MAHMOOD	Mechanical	(04) 392-5316
MOHAMMAD MAHMUD	Electrical	(01) 402-6809 x 309
MOHAMMAD MAHTAB	Electrical	(02) 684-2691
MOHAMMAD MANSHA	Electrical	(01) 2312222 x13733
MOHAMMAD MANSOUR	Architecture	(01) 465-6796
MOHAMMAD MAROOF-UZ-	Electrical	(02) 697-7723
MOHAMMAD MASOOD	Civil	(01) 454-9191 x 214
MOHAMMAD MOAZAM	Civil	(01) 464-1611
MOHAMMAD	Electrical	(01) 426-0018 x 8231
MOHAMMAD MUSLIM	Electrical	(01) 454-8121
MOHAMMAD NADEEM	Electrical	(01) 265-1515 x 517
MOHAMMAD NAEEM	Electrical	(03) 857-2300 x 84561
MOHAMMAD NASIM	Electrical	(01) 403-2222 x 10208
MOHAMMAD NAVEED	Electrical	(03) 361-3407
MOHAMMAD NISAR	Electronics	(03) 343-0333 x 30713
MOHAMMAD NOOR ALAM	Electrical	(01) 401-5555 x 1364
MOHAMMAD PARVEZ	Mechanical	(01) 491-1333 x 325
MOHAMMAD RAFIQUE	Electrical	
MOHAMMAD RASHAD	Electrical	(01) 478-9000 x 3761
MOHAMMAD RASHID	Civil	(03) 592-4445
MOHAMMAD RASHID QAZI	Electrical	(03) 362-1824 x 76597
MOHAMMAD RIAZ	Electrical	(01) 230-3111
MOHAMMAD SADIQ KHAN	Electrical	(01) 403-2222 x 3249
MOHAMMAD SAEED	Mechanical	(03) 887-3868 x 202
MOHAMMAD SAFDAR	Electrical	(03) 858-7536 x 3303
MOHAMMAD SAGHIR	Mechanical	(01) 462-2888
MOHAMMAD SAJID	Electrical	(01) 408-6689
MOHAMMAD SAJJAD	Civil	(03) 899-6835 x 116
MOHAMMAD SALEEM	Electrical	(01) 403-2222 x 1894
MOHAMMAD SALEEM	Electrical	(03) 847-3020 x 232
MOHAMMAD SALEEM	Civil	(03) 860-2691
MOHAMMAD SARDAR	Electrical	(01) 452-7493
MOHAMMAD SHAFIQ	Electrical	(01) 464-9811 x 430
MOHAMMAD SHAFIQ	Civil	(01) 464-5142
MOHAMMAD SHAKIL	Chemical	(03) 847-2466 x 152
MOHAMMAD SHAUKAT ALI	Electrical	(07) 227-1111 x 1410
MOHAMMAD SHEHBAZ	Mechanical	(03) 897-1050 x 272
MOHAMMAD SHER UMAR	Electrical	(03) 857-7738 x 242
MOHAMMAD SULAIMAN	Mechanical	(01) 463-1111 x 2111
MOHAMMAD TAHIR JAMIL	Civil	(03) 833-2266
MOHAMMAD TAHIR	Civil	(01) 460-4845
MOHAMMAD TARIQ	Mechanical	(01) 464-9688
MOHAMMAD TARIQ	Chemical	(03) 857-9922
MOHAMMAD TARIQ	Mechanical	(01) 403-2222 x 1720
MOHAMMAD TARIQ SHAFI	Electrical	(03) 857-9922
MOHAMMAD TAUSIF	Electrical	(01) 403-2222 x 23197
MOHAMMAD TAYYIB	Civil	(01) 454-9191 x. 256
MOHAMMAD TOUSEEF	Electrical	(03) 577-1405
MOHAMMAD WAQAR	Mechanical	(04) 396 1366 x 104
MOHAMMAD WASEEM	Architecture	(01) 252-0088 x 4563
MOHAMMAD YAHYA KHAN	Civil	(01) 454-9191 x 292
MOHAMMAD YAQUB	Mechanical	(03) 860-2520
MOHAMMAD YASIN	Mechanical	(03) 678-8288 / 895-5004
MOHAMMAD YOUNAS	Mechanical	(03) 860-3049
MOHAMMAD YOUNAS	Chemical	(01) 285-1878
MOHAMMAD YOUNAS	Chemical	(03) 357-2327
MOHAMMAD YOUSAF	Mechanical	(03) 868-2255 x 234
MOHAMMAD YOUSUF	Civil	
MOHAMMAD ZAFAR	Chemical	(01) 265-0980
MOHAMMAD ZAFAR	Mechanical	(0) 403-2222 x 29760
MOHAMMAD ZAFAR	Electrical	(01) 441-5958
MOHAMMAD ZAHID	Mechanical	(03) 8576024
MOHAMMAD ZAMURRAD	Electronics	(01) 452-5161
MOHAMMED MAHMOOD	Electrical	(03) 892-2300 x 2503
MOHAMMED RASHID	Electrical	(02) 663-7854
MOHAMMED SALEEM	Architecture	(02) 654-7171 x 388
MOHIUDDIN AHMED	Mechanical	(03) 860-3779
MOHSIN TANVIR MALIK	Electrical	(02) 672-5405
MUBEEN UDDIN AHMED	Civil	(03) 576-0650 x. 195
MUJAHID AHMAD	Electrical	(01) 478-9000 x 3976
MUKESH KUMAR	Electrical	(03) 899-5605 / 898-0071
MUKHTAR AHMAD FAZAL	Electrical	(01) 403-2222 x 23222
MUNAWAR A.	Chemical	(01) 265-3333 x 5545
MUNAWAR HUSSAIN	Electrical	(01) 403-2222 x 1232
MUNEEB AHMAD DAR	Electrical	(07) 227-1111 x 1106
MUNEER AHMED RANA	Civil	(01) 460-7667
MUNIR AHMAD	Civil	(01) 403-1103
MUNIR AHMAD HASRAT	Electrical	(01) 411-2222 x 3324
MUNIR AHMED	Electrical	(01) 265-3030 x 1330
MUNIR AHMED	Civil	(01) 490-0116
MUNIR AHMED JAVID	Civil	(03) 889-1609
MUSHARRAF ALI KHAN	Electrical	(01) 265-0255 x 15
MUSHIR AHMED SIDDIQUI	Electrical	(01) 481-6666 x 318
MUSHTAQ AHMED AZAD	Electrical	(03) 858-5786
MUSHTAQ AHMED	Electronics	(01) 403-2222 x 10346
MUSHTAQ AHMED M.	Electrical	(07) 227-1111 x 1750
MUSHTAQ AHMED	Electrical	(01) 403-2222 x 23203
MUSHTAQ AHMED	Civil	(02) 654-7171 x 159
MUSTAFA IQBAL NASIM	Civil	(01) 401-2550 x 617
MUSTAFA NOEED AHMED	Civil	(03) 842-2442
MUZAFFAR UL HASSAN	Electrical	(01) 241-3300 x 24797
NADEEM ARSHAD SHEIKH	Civil	(01) 465-9975 x 213
NAEEM AKHTAR	Civil	(03) 860-2691
NAEEM UD DIN	Electrical	(01) 241-3236 x 4165
NAEEM ULLAH SHEIKH	Electrical	(01) 265-1573 x 240

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NAME	DISCIPLINE	PH. (OFFICE)
NAFIS-UL-HASAN	Mechanical	(01) 498-0020 x 7013
NAJIB REHMAN	Mechanical	(02) 654-7171 x 130
NASIM R.M INAMULLAH	Mechanical	(01) 245-3681 x 9753
NAVEED AHMAD, PMP	Electrical	(01) 265-3030 x 1534
NAVEED AKHTAR	Electrical	(01) 464-9390
NAVEED IQBAL QURESHI	Mechanical	(01) 477-7009 x 27213
NAVEED ULLAH	Civil	(03) 859-4015
NAYER AZAM	Electronics	(01) 416-2222 x 440
NAZAR HUSSAIN MALIK,	Electrical	(01) 467-6783
NAZAR MOHAMMAD	Architecture	(01) 476-3030
NEAZ AHMED	Mechanical	(03) 860-3082
NISAR AHMAD ATTA	Mechanical	(07) 227-1111 x 1295
NISAR BALOCH	Electrical	(01) 291-2877 x 24
NOOR MOHAMMAD KHAN	Electrical	(01) 464-3333 x 14851
NOOR ULLAH KHALID	Architecture	(01) 461-6087 x 166
NUSRAT PERVEZ	Electronics	(01) 463-1277 x 401/404
OBAIDULLAH SIDDIQI	Civil	(01) 476-3030 x 289
OMER FAROOQ SALAM	Chemical	
PARVEZ A. NAUSHAHI	Civil	(03) 894-8215
PERVAIZ AKBAR	Mechanical	(03) 341-6430 / 341-0671
PERVAIZ IQBAL QURESHI	Civil	(01) 465-6150
QAIM MAHDI	Electrical	(01) 265-1515 x 316
QAIYYUM HASHMI	Civil	(03) 897-1050 x 788
QAMAR UL ISLAM	Computer	(01) 478-3603 x 263
QAMARUL HAQUE	Electrical	(02) 669-5851 x 242
QAZI SALEEM AHMED	Electrical	(02) 669-5851 x 251
RAFIQ AHMED	Electrical	(01) 465-6975
RAJA SHAHID SALEEM	Civil	(03) 833-3997
RANA SARFRAZ AHMED	Electrical	(01) 452-8905
RAO ABDUL RAQEEB	Electrical	(01) 452-6964
RASHID A. BHUTTO	Electrical	(07) 227-1111 x 1320
RAZA HUSAIN	Electrical	(01) 465-9975 x 205
RAZAUR RAHMAN	Electrical	(01) 265-1515 x 255
REHAN NOOR KHAN	Mechanical	(03) 896-6666 x 1045
RIAZ HUSSAIN	Electronics	(01) 452-8712
RIZWAN AHMAD	Electrical	(03) 834-1730
RIZWAN AHMED BHATTI	Civil	(03) 897-1050 x 159
RIZWAN ALI	Mechanical	(03) 341-0671
RIZWAN UL HAQ FAISAL	Electrical	(03) 857-9922 x 227
RUKHSUDDIN SHAIKH	Architecture	(01) 491-7880
S. AADIL USMAN FATIMI	Computer	(01) 246-1200
S. ABID HUSSAIN	Mechanical	(01) 491-1333 x 320
S. AFZAL HASAN KAZMI	Electrical	(01) 465-2511 x 14
S. AIJAZ HAIDER	Electrical	(02) 6614444x 2406
SADAR DIN	Civil	(01) 465-9975 x 203
SAEED RASHID SHEIKH	Mechanical	(01) 476-2539
SAFDAR A. KHAN	Electrical	
SAFDAR IQBAL AWAN	Electrical	(01) 464-3333 x 14386
SAGHIR AHMED	Electrical	(03) 343-0333 x 39204
SAIF UR REHMAN	Mechanical	(01) 491-1333 x 342
SAIFULLAH SALEEM	Mechanical	(01) 204-6279
SAIF-UR-RAHMAN, DR	Mechanical	(03) 860-6688
SAJID ALI KHAN	Electronics	(03) 341-1100 x 863
SAJJAD AHMAD SAJID	Electrical	(02) 665-8420 x 2047
SALEEM AHMAD	Electrical	(03) 586-8600 x 62679
SALEEM BAIG MIRZA	Civil	(01) 477-8384
SALEEM GHOUS KHAN	Miscellaneous	(03) 860-4730
SALMAN M. KHAN	Civil	(03) 874-6859
SALMAN MEHMOOD	Electronics	(03) 865-5422
SALMAN MUSTAFA	Electrical	(03) 566-2072
SAMI UDDIN CHUGHTAI	Mechanical	(03) 868-2255
SAQIB SHAH	Electrical	(01) 464-1188 x 292
SARFRAZ AHMAD MALIK	Mechanical	(03) 357-7236
SARFRAZ MAHMOOD	Electrical	(01) 452-8519
SHABBIR A. KHOKHAR	Civil	(01) 477-4002 x 248
SHABBIR AHMED BUTT	Architecture	(02) 675-7253
SHABBIR AHMED	Mechanical	(01) 465-9975
SHAH NAWAZ KHAN	Electrical	(07) 227-1111 x 1381
SHAH ZAMAN PANHWAR	Electrical	(02) 660-3672
SHAHABUDDIN	Miscellaneous	(01) 523-5529
SHAHID AKHTAR BUTT	Electrical	(03) 357-7320
SHAHID AKRAM	Electrical	(01) 479-0345 x 4100
SHAHID ANWAR	Civil	(01) 249-9270
SHAHID MASOOD	Mechanical	(03) 572-0059
SHAHID YOUNUS KHAN	Mechanical	(03) 358-4000 x 205
SHAHID ZUBAIR	Electrical	(01) 265-1515 x 507
SHAHZAD ALI BAIG	Electrical	(03) 882-9394
SHAIKH ASRAR AHMED	Electronics	(01) 473-8995 / 473-8996
SHAIKH MOHAMMAD	Civil	(01) 472-4338
SHAKEEL AHMAD	Electrical	(01) 402-0227
SHAKIL AHMAD	Electrical	(03) 722-3111 x 73159
SHAKIL OMAR	Electrical	(03) 857-7738
SHAMEEM AHMAD	Mechanical	(03) 343-0333 x 31002
SHAMIM AHMED	Mechanical	(03) 341-0671
SHAMIM ALAM KHAN	Electrical	(01) 403-1128
SHAMIM UDDIN	Mechanical	(01) 464-1188 x 226
SHAMS-UD-DIN AHMED	Mechanical	(03) 340-1606
SHAMS-UR-REHMAN	Mechanical	(01) 230-0567
SHARFUDDIN	Mechanical	(03) 343-0333 x 31002
SHARFUDDIN S. MALIK	Miscellaneous	(01) 465-9975
SHAUKAT ALI	Electrical	(03) 860-4252
SHAUKAT PERVAIZ	Mechanical	(01) 478-4401
SHEHZAD AHMED	Electrical	(04) 397-4005
SHEIKH AKHTAR HUSAIN	Civil	(01) 465-9975 x 240
SHEIKH KHALIL AHMED	Civil	(01) 454-9191 x 225
SHEIKH MAHMOOD	Electrical	(03) 373-0308 x 72634
SHEIKH MUHAMMAD	Mechanical	(07) 227-1111 x 1124
SHIEKH NISAR	Mechanical	(07) 227-1111 x 1306
SHOAIB AHMAD	Electrical	(03) 867-7838
SIKANDER JAVED KHAN	Mechanical	(03) 358-4000 x 414
SIRAJ UL HUDA SIDDIQUI	Mechanical	(01) 464-1188 x 203
SULTAN ALI MANZOOR	Electrical	(03) 858-7075 x 37
SYED ABDUR REHMAN	Mechanical	(01) 491-1333 x 431
SYED ABUL HASAN JAFRI	Electrical	(02) 665 4616
SYED ADNAN ALI	Electronics	(01) 462-9095 x 5313
SYED ADNAN MOID	Electrical	(01) 462-5858 x 248
SYED AFZAL HUSAIN	Electrical	(01) 465-4406
SYED AHMED MAHMOOD	Mechanical	(02) 640-0004 x 378
SYED ALI ABID	Mechanical	(01) 491-1333 x 303
SYED ALI HAROON	Chemical	(03) 827-1652
SYED AMIR UR REHMAN	Electrical	(03) 835-8875
SYED ANWAR ALI	Mechanical	(03) 857-2300 x 84951

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NAME	DISCIPLINE	PH. (OFFICE)
SYED ASHFAQUE	Electronics	(02) 671-7285
SYED ASLAM ALI	Mechanical	(03) 894-6816 x 259
SYED FAIZ AHMAD	Civil	(01) 477-3115 x 3845
SYED FARID MUSTAFA	Electrical	(03) 882-5669
SYED GHULAM MUSTAFA	Civil	(01) 454-9191
SYED HUSSAIN HAIDER	Electrical	(03) 899-9900 x 45
SYED IBNE MOHAMMAD	Civil	(03) 340-1249
SYED IFTIKHAR AHMED	Electronics	(03) 574-4115
SYED IQBAL ALAM	Computer	(01) 476-3777 x 367
SYED ITRAT HUSSAIN	Mechanical	(01) 246-4632
SYED KAFIL AHMED	Mechanical	(03) 566-0600 x 525
SYED KHALID UMER	Mechanical	(01) 206-6909
SYED KHAWAJA NEHAL	Electronics	(01) 495-1300 x 228
SYED KHURSIED ABBAS	Electronics	(04) 396-6176
SYED MANSOOR AHMED	Electrical	(01) 462-2888 / 464-2356
SYED MANZAR HASNAIN	Mechanical	(01) 464-9688
SYED MASOODUL	Mechanical	(03) 857-2300 x 84980
SYED MOHAMMAD ALI	Civil	(03) 833-3997
SYED MOHAMMAD	Electrical	(01) 464-9688
SYED MOHAMMAD	Mechanical	(03) 860-3135
SYED MOHTASHIM NIZAM	Mechanical	(03) 895-5004
SYED MUBASHIR UL	Electrical	(01) 474-0555 x 191
SYED MURSHID PERVEZ	Electrical	(01) 406-9200 x 278
SYED NAEEM ALI	Architecture	(02) 654-7171
SYED NASIR UDDIN	Mechanical	(02) 651-9998 x 235
SYED NAVED HAIDER	Electrical	(03) 882-5669 x 223
SYED NAZEEF AKHTER	Electronics	(01) 454-9191 x 275
SYED NIAZ AHSAN	Metallurgy	(03) 359-9210
SYED RAHEEL AZAM	Electrical	(03) 864-1012
SYED SAFDAR RAZA	Mechanical	(01) 463-1111 x 5182
SYED SAJID HUSSAIN	Mechanical	(01) 401-2550 / 41765816
SYED SALIMULLAH	Electronics	(01) 419-1394
SYED SALMAN SHAFIQ	Computer	(01) 452-6275
SYED SAMIUDDIN AHMED	Civil	(03) 895-5004 x 242
SYED SHABBIR AHMED	Electrical	(01) 403-2222 x 29716
SYED SHAHERYAR A	Electrical	(01) 401-2550 x 608
SYED SHAKEEL AHMED	Electronics	
SYED SHAMSUL HAQ	Electrical	(01) 472-4238
SYED TASNEEM HUSAIN	Electrical	(01) 265-1689 x 1482
SYED TOUSEEF AHMAD	Electrical	(01) 465-9975
SYED UMER MOIZ	Electrical	(01) 467-2759
SYED WAJID HUSSAIN	Electrical	(03) 858-4855 x 307
SYED WALIULLAH	Mechanical	(02) 667-0092 x 336
SYED WASI IMAM	Civil	(03) 895-5004 x 239
SYED WIQAR FAKHRI	Electrical	(03) 378-3581
SYED ZAFAR AHMAD	Mechanical	(01) 476-9777 x 42310
SYED ZAFAR WAHAB	Electrical	(03) 586-8600 x 62864
SYED ZAHID HASSAN	Electrical	(01) 403-2222 x 3150
SYED ZAHIR-UL-HUSNAIN	Civil	(03) 820-4309
SYED ZIKRUR REHMAN	Mechanical	(01) 467-6966
TAHIR ALI	Mechanical	(03) 357-7327
TAHIR ILYAS SHEIKH	Mechanical	(01) 464-3500 x 263
TAHIR RASHID KHAN	Mechanical	(03) 348-2440
TAHIR S. MIRZA	Electrical	(03) 858-6201
TANWEER AHMED	Electrical	(01) 265-0850
TANWEER EJAZ NAWAZ	Electrical	(03) 858-6725
TANWEER NAWAZ MALIK	Electrical	(01) 275-5999 x 4458
TARIQ AHMED SHEIKH	Metallurgy	(07) 227-1111 x 1301
TARIQ ALI KHAN	Chemical	(03) 847-4050
TARIQ BIN ZAFAR	Mechanical	(03) 859-0484
TARIQ MAHMOOD	Chemical	(01) 498-4000 x 1888
TARIQ MUMTAZ SOOMRO	Electrical	(01) 293-3617 / 464-3082
TARIQ MUSHTAQ	Electrical	(03) 858-5471
TASADDUQ HUSSAIN	Electronics	(01) 206-0000 x 3334
TASNEEM AHMED	Electronics	(03) 858-7505 / 858-7595
TAZIM HUSSAIN KAZIM	Miscellaneous	(02) 671-7717 x 529
UMAR HAYAT RANA	Electrical	(03) 858-6647
WAHEED AKHTER	Electronics	(01) 464-9811 x 430
WAJAHAT HUSSAIN	Electrical	(02) 640-0004 x 265
WAQAR AHMAD	Mechanical	(01) 465-9975 x 219
WAQAR USMAN MIAN	Metallurgy	(03) 832-4400 x 564
WASEEM NOOR MALIK	Civil	(01) 454-9191 x 224
WAZIR ULLAH KHAN	Electrical	(03) 889-1609
YASER MAHMOOD	Electrical	(01) 403-2222 x 1225
YASER MUSHTAQ	Electrical	(01) 265-2112 x 1516
YASIN KHAN, DR.	Electrical	(01) 467-9813
ZAFAR AHMED TALPUR	Mechanical	(02) 691-6240
ZAFAR IQBAL	Electrical	(01) 478-2027
ZAFARULLAH KHAN DR.	Mechanical	(03) 860-2693
ZAHEER UDDIN AHMAD	Mechanical	(01) 498-2807 x 455/ 498-
ZAHID KHAN	Electronics	(07) 227-1111 x 1410
ZAHOOR ALI KHAN	Computer	(01) 435-5010 x 731
ZAINULABDIN PATHAN	Civil	(01) 403-2222 x 29758
ZAKIR RAZA	Electrical	(01) 477-7000
ZUBAIR AHMED	Electrical	(01) 465-6975
ZUBAIR AKHTAR	Mechanical	(01) 463-1111 x 2805
ZULFIQAR AHMED	Electrical	(01) 477-1122 x 258
ZULFIQAR AHMED KHAN	Mechanical	(01) 495-1629

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2. **COMSATS Institute of Information Technology (Islamabad Campus), Islamabad (http://www.ciit.edu.pk/)**
   - B.Sc. Computer Engineering, w.e.f. the Intake Year 1999. (Re-accreditation is under process)
3. **Bahria University, (Islamabad Campus))**
   - B.Sc. Computer Engineering, Accredited for One Year (Intake Fall 2001)
   - B.Sc. Software Engineering, Accredited for One Year (Intake Spring 2001)

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2. **Institute of Chemical Engineering and Technology, Lahore (University of Punjab)**
   - B.Sc. Engineering (Chemical, Metallurgy & Materials Science)
3. **University of Agriculture, Faisalabad (http://www.uaf.edu.pk/)**
   - B.Sc. (Agricultural Engineering). Re-accredited for one year for entry year 2001.
4. **NFC Institute of Engineering and Technological Training, Multan (Bahauddin Zakariya University)**
   - B.Sc. Engineering (Chemical). Accreditation expired in the year 2003. (Re-accreditation is under process)
5. **College of Electrical & Mechanical, Rawalpindi (NUST) (http://www.nust.edu.pk/)**
   - B.E. (Electrical, Mechanical and Computer)
   - B.E. (Mechatronics). Re-accreditation is under process.
6. **Military College of Signals, Rawalpindi (NUST) (http://www.nust.edu.pk/)**
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9. **National Textile University, Faisalabad (http://www.ntu.edu.pk/)**
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   - B.E. (Computer Systems and Textile). Re-accredited for one year, will be revisited in 2005.
2. **Institute of Industrial Electronics Engineering (PCSIR), Karachi (NED UET)**
   - B.E. (Industrial Electronics). Re-accreditation is over due.
3. **Mehran University of Engineering and Technology, Jamshoro (http://www.muet.edu.pk/)**
   - B.E. (Civil, Electrical, Mechanical, Electronics, Industrial, Pet-gas, Computer System, Chemical, Metallurgical and Mining).
   - B.E. (Textile). Awarded to persons admitted in 1994 and after, subject to review after one year i.e., in 2003.
   - B.E. (Telecommunication, Software). Accredited for One Year (Entry Year 2001).

4. **Usman Institute of Technology, Karachi (Hamdard University) (http://www.uit.edu/)**
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   - B.Sc. (Electrical Engineering). Re-accredited for one year for entry year 2003.
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7. **Gandhara Institute of Science & Technology, PGS Engineering College (NWFP UET), Peshawar**
   - B.Sc. (Civil Engineering, Electrical Engineering). Accredited for one year for entry year 2001.
8. **COMSATS Institute of Information Technology (Abbottabad Campus), Abbottabad**
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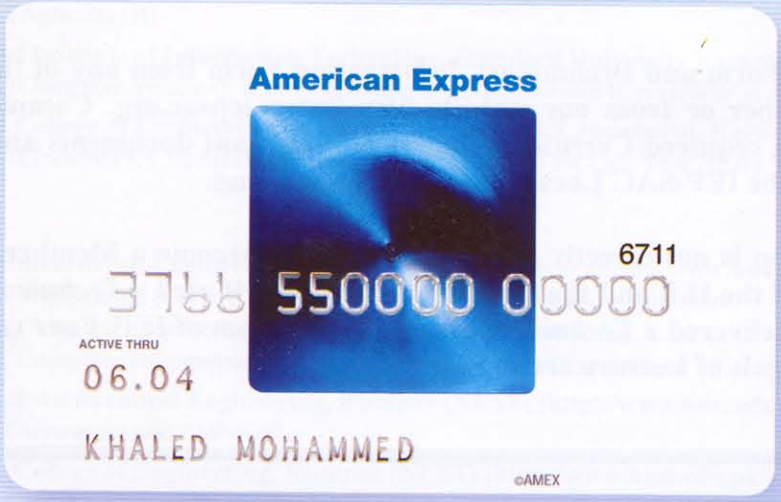

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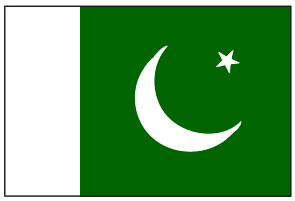

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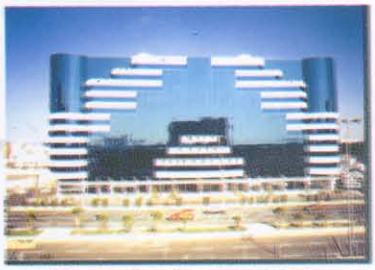

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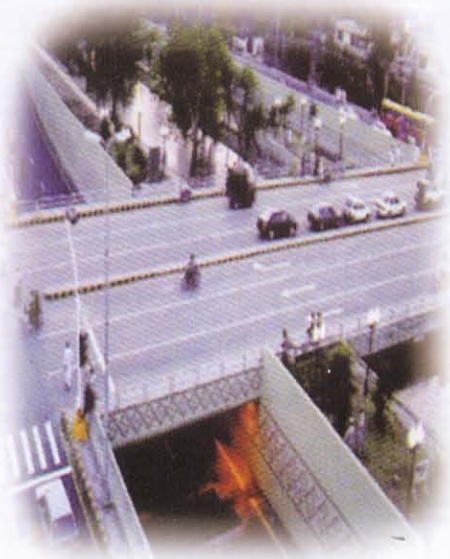

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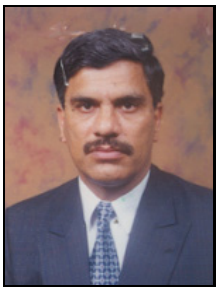

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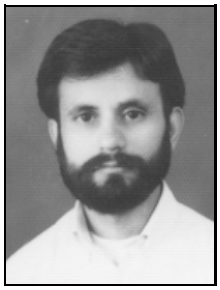

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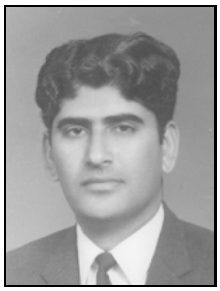

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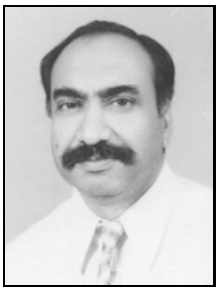

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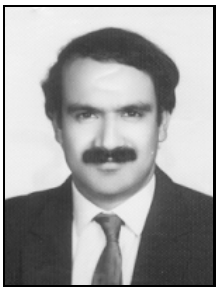

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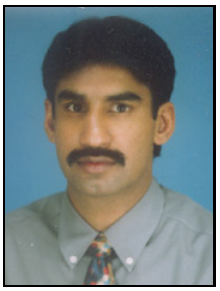

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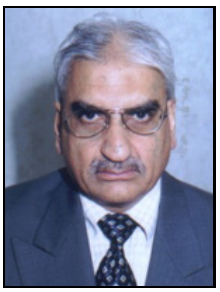

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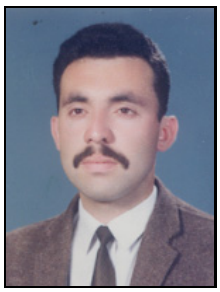

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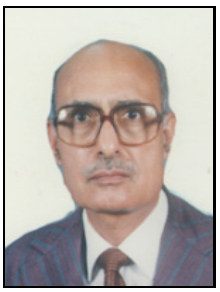

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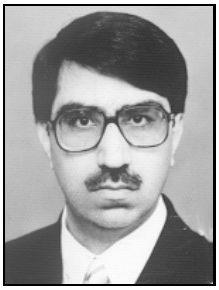

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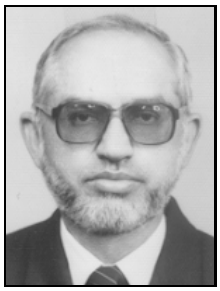

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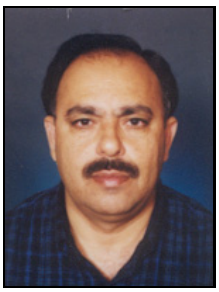

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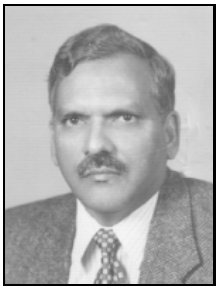

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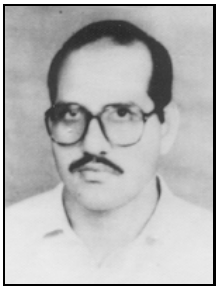

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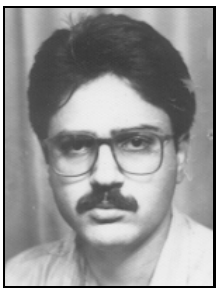

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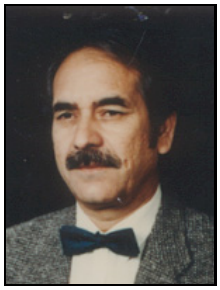

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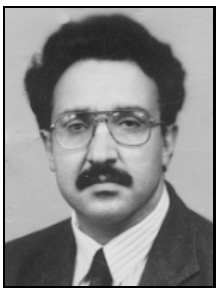

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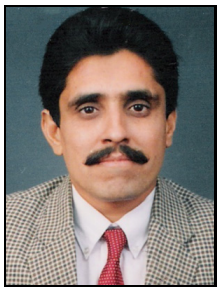

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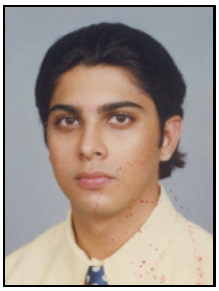

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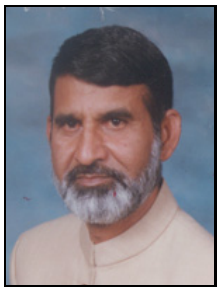

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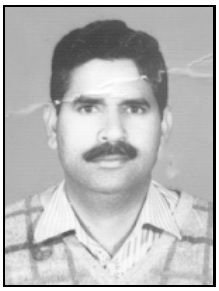

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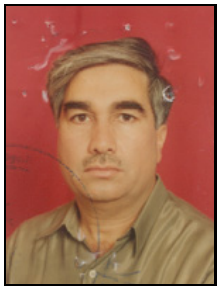

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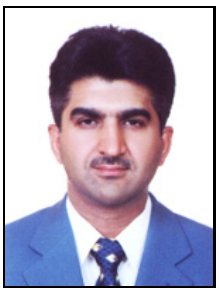

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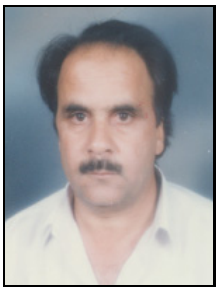

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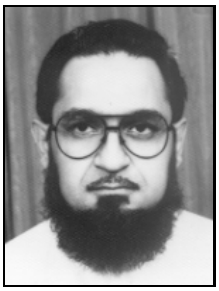

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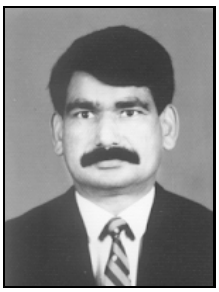

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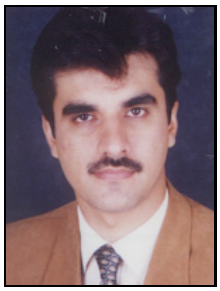

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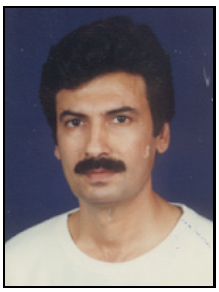

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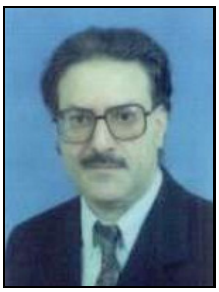

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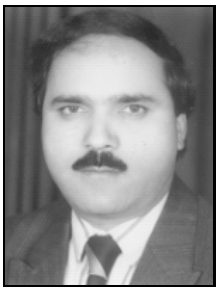

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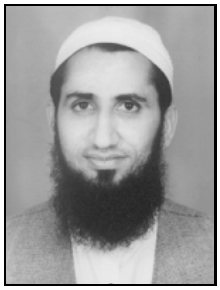

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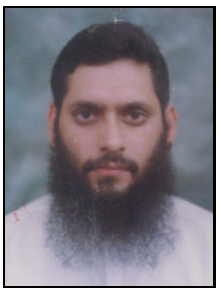

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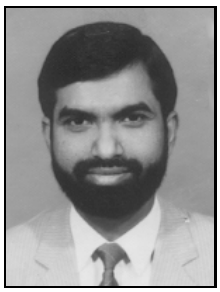

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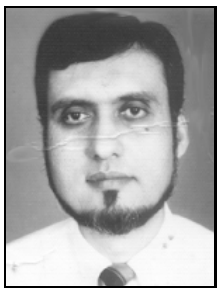

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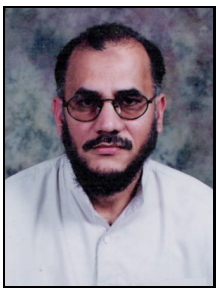

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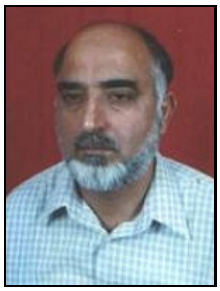

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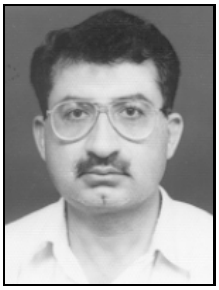

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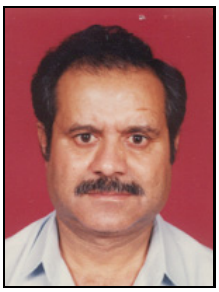

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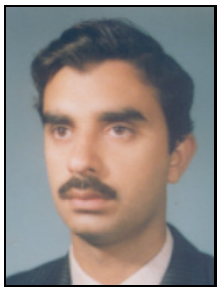

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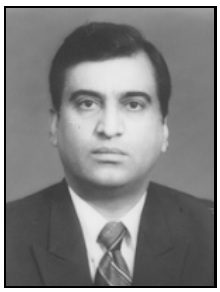

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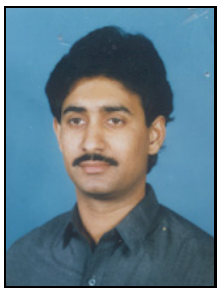

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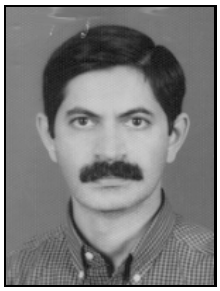

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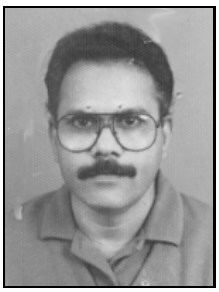

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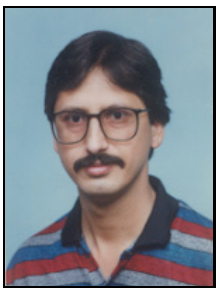

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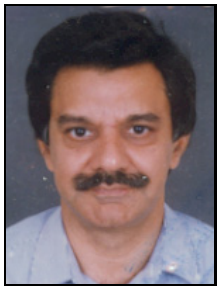

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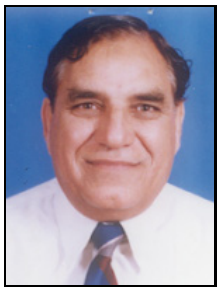

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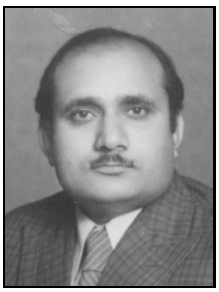

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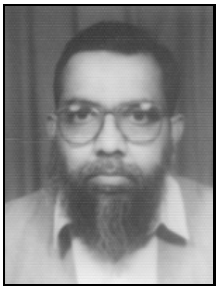

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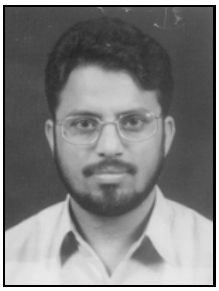

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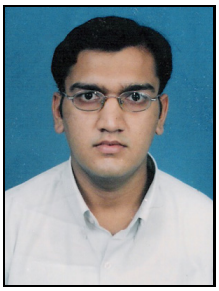

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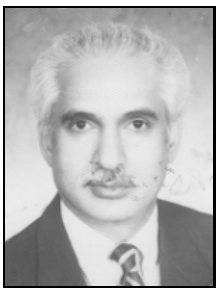

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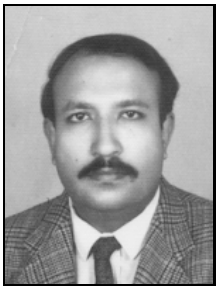

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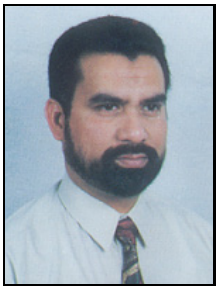

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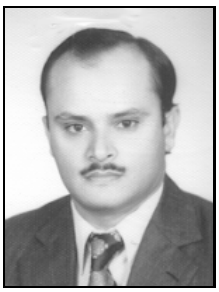

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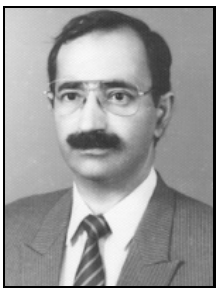

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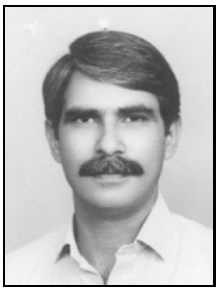

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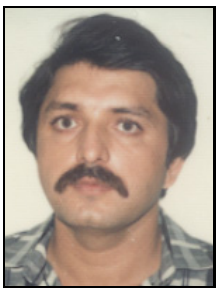

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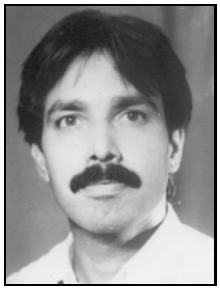

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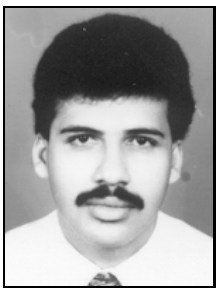

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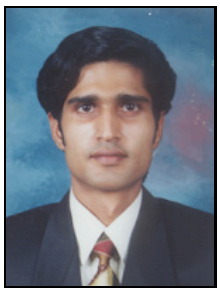

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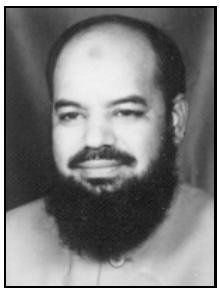

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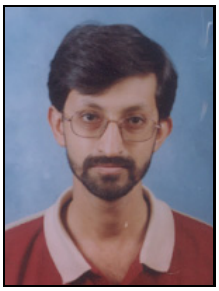

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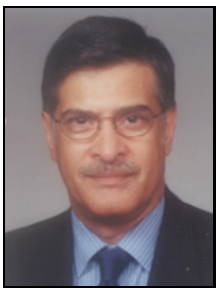

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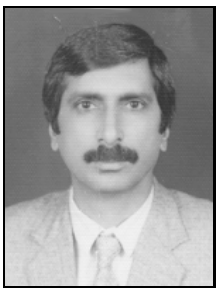

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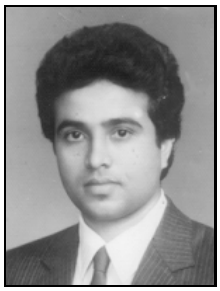

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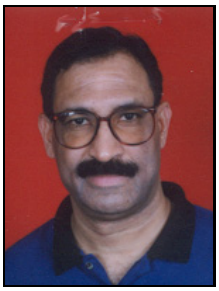

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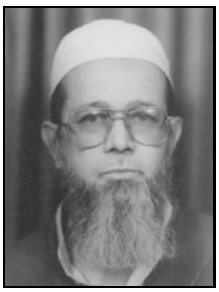

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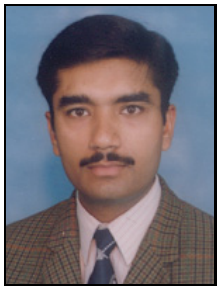

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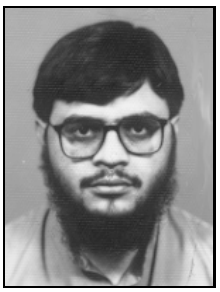

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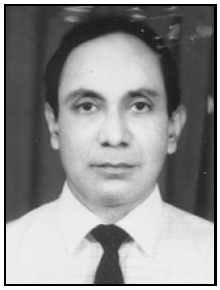

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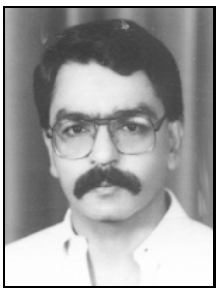

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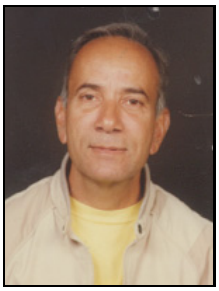

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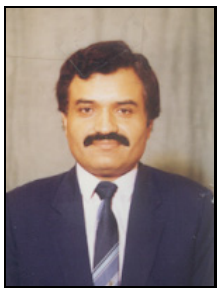

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ACRONYM AND ABBREVIATIONS

AE	Associate Engineer
AEC	Ahsanullah Engineering College, Dacca
Aero	Aeronautical Engineering
Agr	Agricultural
AIT	Asian Institute of Technology, Bangkok, Thailand
AMU	Aligarh Muslim University, India
AUB	Astonton University, Birmingham
AUUP	Allahabad University, UP, India
BCE	Bihar College of Engineering
BU	Baluchistan University, Pakistan
BUE	Birmingham University, England
CBA	College of Business Administration, Lahore
CE	Civil Engineering
CEI	Council of Engineering Institution, UK
CET	College of Engineering, Taxila, Pakistan
Chem	Chemical Engineering
CMSU	Central Missouri State University, USA
Comp	Computer
CPU	California Pacific University, USA
CSU	California State University, USA
DCET	Dawood College of Engineering & Technology, Karachi, Pakistan
DIT	Detroit Institute of Technology, USA
DU	Duke University, USA
DUP	Drexel University, Philadelphia, USA
E	Electrical
Ecs	Electronics
Env	Environmental
EE	Electrical Engineering
EPUET	East Pakistan University of Engineering & Technology, Dacca
ET	ENSAE Toulouse, France
GCTK	Govt. College of Technology, Karachi
GIK	G. I. K. Institute of Engineering and Technology, Topi, Pakistan
GPIS	Govt. Polytechnic Institute, Sialkot, Pakistan
GT	Georgia Tech, USA
GWU	George Washington University, USA
HP	Huddersfield Polytechnic, UK
HWU	Heroit Watt University Edinburg, UK
IBA	Institute of Business Administration, Karachi
ICES	Institute of Civil Engineering Surveyors, UK
ICUL	Imperial College University of London, UK
IEEL	Institution of Electrical Engineers London, UK
IEP	Institution of Engineers Pakistan Exam Section A&B
IIT	Illinois Institute of Technology, Chicago, USA
Ind	Industrial
IQA	Institution of Quality Assurance, UK
IU	International University
KCL	King's College London, UK
KFUPM	King Fahad University of Petroleum & Minerals, Dhahran, Saudi Arabia
KFUPM-RI	King Fahad University of Petroleum & Minerals-Research Institute
KU	Karachi University, Pakistan
KWU	Kennedy Western University, USA
LP	Liverpool Polytechnic
LU	Lamar University, Texas, USA
M.E.	Master of Engineering
M.S.	Master of Science
ME	Mechanical Engineering
MEH	Mehran Engineering University, Jamshoro
Met	Metallurgical Engineering
METU	Middle East Technical University, Ankara, Turkey
Min	Mining
MiSU	Mississippi State University, USA
MMU	Manchester Metropolitan University, UK
MOPTT	Ministry of Post, Telegraph and Telephone, Saudi Arabia
MSU	Michigan State University, USA
MTU	Michigan Technology University, USA
MUET	Mehran University of Engineering & Technology, Jamshoro
NCA	National College of Arts, Lahore
NCET	National College of Engg. & Technology, Karachi, Pakistan
NED	NED College/University of Engineering & Technology, Karachi
NEU	Near East University
NU	Northrop University, USA
Nuc	Nuclear Engineering
NWFPUET	North West Frontier Province Uni. of Engg. & Tech., Peshawar, Pakistan
Off.	Office
OSU	Ohio State University
OU	Osmania University, Hyderabad
OUM	Oakland University, Michigan, USA
PAFCAE	Pakistan Air Force College of Aeronautical Engineering, Karachi
PCET	Punjab College of Engineering & Technology, Lahore
PCOA	Pakistan College of Aeronautical Engineering
PE	Petroleum Engineering
Pet	Petroleum
PGC	Post Graduate Course
PGD	Post Graduate Diploma
PIBR	Polytechnic Institute Bucharest, Rumania
PINSTC	Pakistan Institute of Science & Technology, Islamabad
PNEC	Pakistan Navy Engineering College
PSU	Penn. State University, USA
PU	Punjab University, Lahore
PUI	Purdue University, West Lafayette, Indiana, USA
PUK	Preston University, Karachi, Pakistan
QAU	Quaid-e-Azam University Islamabad
Res.	Residence

RU	Ranchi University, India
RUH	Rice University Huston, USA
S	Systems
SGW	Sir George Williams, Canada
SIU	Southern Illinois University, USA
Sr.	Senior
SSUET	Sir Syed University of Engineering and Technology, Karachi, Pakistan
SU	Sind University, Jamshoro, Pakistan
SUC	Stanford University, California, USA
TSC	Telecom. Staff College, Haripur, Pakistan
TUB	Technical University, Berlin, Germany
U	University
UB	University of Bahrain
UD	University of Detroit, Michigan, USA
UDE	University of Durham, England
UETL	University of Engineering and Technology, Lahore, Pakistan
UL	University of Leeds, UK
UM	University of Michigan, Ann Arber, USA
UNSW	University of New South Wales, Australia
UOB	University of Bradford, UK
UOBE	University of Birmingham, UK
UOC	University of California, USA
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UOS	University of Salford, UK
UOT	University of Engineering and Technology, Taxila
UOW	University of Waterloo, Canada
UPM	University of Petroleum & Minerals, Dhahran, Saudi Arabia
US	University of Southampton, UK
USC	University of Southern California, Los Angeles, USA
UTA	University of Texas, Austin, USA
UTC	University of Toronto, Canada
UW	University of Windsor, Ontario, Canada
WSU	Washington State University, USA
WU	Winconsin University, USA
x	Extension

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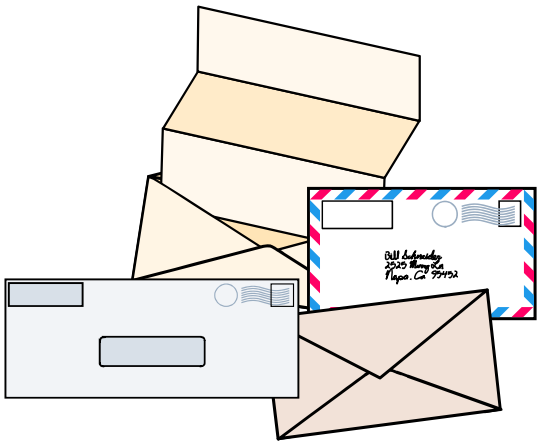

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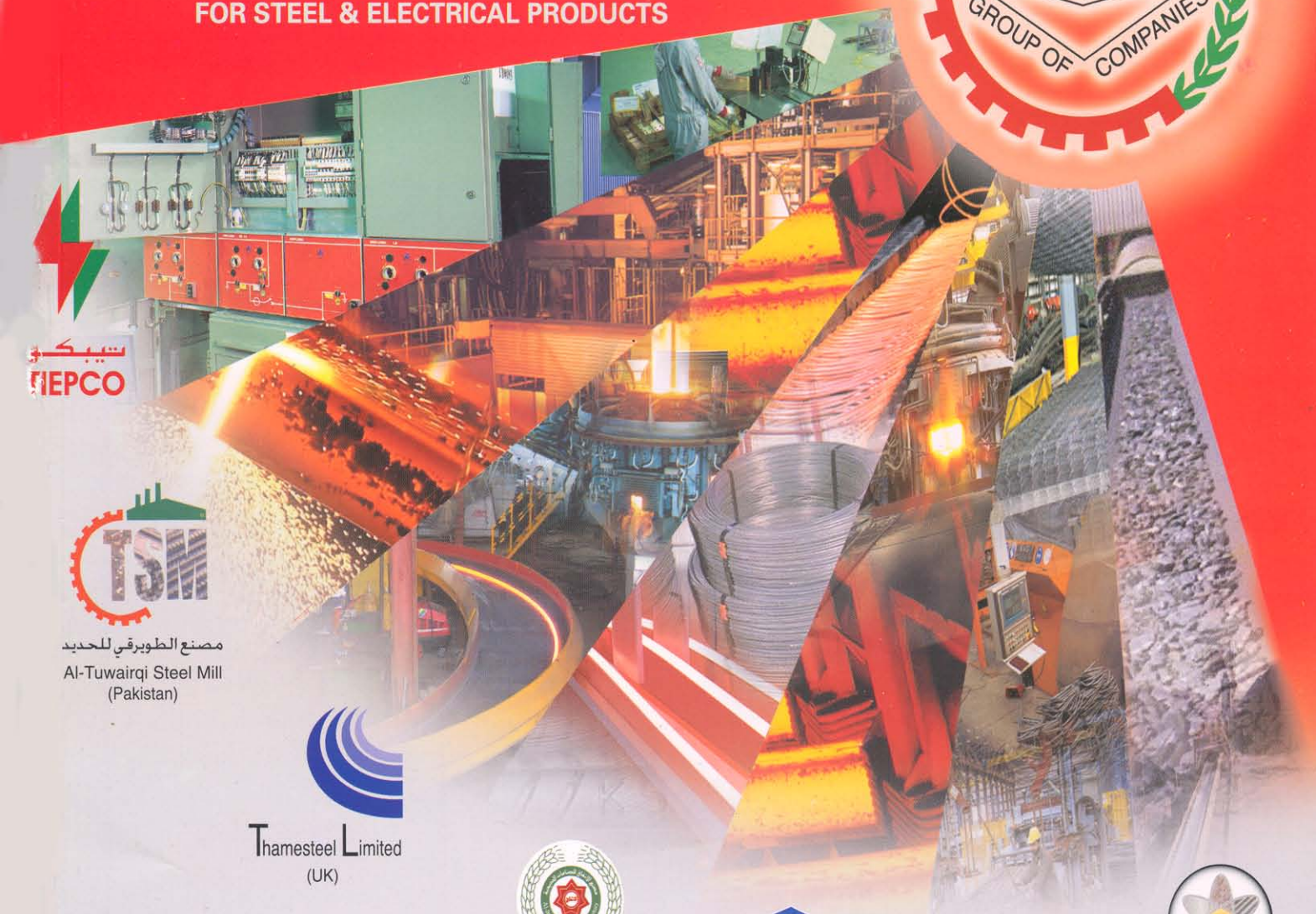

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