ISSN 1024-6223

The Pakistan Engineer

Vol 62, Issue 2
April - June 2015

Horizontal Axis Wind Turbine Blade Manufacturing Through Vartm

(Vacuum Assisted Resin Transfer Molding) p/5

A Publication of
The Institution of
Engineers, Pakistan

"If Pakistan is to take its proper place among the progressive nations of the world, it will have to take up good deal of leeway in the realm of scientific and technical education which is so necessary for the proper development of the country and the utilization of its resources. The establishment of institution like the Institute of Engineers will greatly stimulate technical research and help in disseminating available information. The Institute of Engineers will not only benefit the engineers themselves by improving their technical knowledge but also bring lasting benefit to public services which they are called upon to perform.

I wish the Institute every success".

(Quaid-e-Azam's message to the first inaugural meeting of the Institute of Engineers on 20th June 1948)

Published By
The Institution of Engineers, Pakistan

Engr. Muhammad Ashraf
Director General

Business Offices
Raja Muhammad Rafique
Director Admin & Publications

IEP Headquarters Building,
Engineering Centre,
Main Boulevard, Gulberg-III,
Lahore, Pakistan
Ph: 042-35754043, 35750699

Fax: 042-35759449
e-Mail: iephqr@gmail.com

Graphics & Composing
Mian Abid

Printers
Amjad Printer
Urdu Bazar, Lahore

ISSN 1024-6223 Regd. L. No: 8070

The Pakistan Engineer

Vol 62, Issue 2

Contents

The Pakistan Engineer

Magazine of The Institution of Engineers, Pakistan

Advertisement Tariff

LOCATION	SIZE	RATE PER INSERTION		REMARKS
		B&W	COLOR	
FRONT PAGE	--	--	--	Reserve for Title
INSIDE FRONT PAGE	--	--	--	Reserve for Quaid's Message
BACK PAGE	(210.0 mm x 297.0 mm) (A4)	--	30,000/-	Reserve for Ad in Color
INSIDE BACK PAGE	(210.0 mm x 297.0 mm) (A4)	--	25,000/-	Reserve for Ad in Color
ANY OTHER PAGE	(210.0 mm x 297.0 mm) (A4)	15,000/-	20,000/-	Available for Ads
ANY OTHER PAGE	(148.0 mm x 210.0 mm) (A5)	10,000/-	15,000/-	Available for Ads

The Institution of Engineers, Pakistan

For information & booking please contact:

Raja Muhammad Rafique,
Director Admin Publication
IEP Headquarters Building,
Main Boulevard, Gulberg-III, Lahore
Ph: 042-35754043, 35750699, Fax: 042-35759449
E-mail: iephqr@gmail.com, URL: www.iep.com.pk

Horizontal Axis Wind Turbine Blade Manufacturing through VARTM

[VACUUM-ASSISTED RESIN TRANSFER MOLDING]

Engr. Muhammad Muzamil
muzamil@neduet.edu.pk

Engr. Daniyal Rizwan

Engr. Hassan Mehboob

Engr. Umair Mohiuddin

Engr. Sadiqeen Noor

Abstract
The use of composite materials have been growing recently for structural application due to some novel properties over metals. The use of Vacuum assisted Resin Transfer Molding (VRTM) is become popular technique for the manufacturing of small and medium wind turbine blades. This process has great advantages over the conventional method (Hand Layup Method) like increase structural reliability, lower the blade weight, consistent fiber volume or orientations and mechanical strength. The presented work is to develop the setup of VRTM process through which the two halves of wind turbine blade can be manufactured separately, then assembled together to form the complete structure. The selected airfoil shape was NREL S822 with 1.2 meters in blade length. The blade is made from three layers of S-glass woven roving cloth as fiber and unsaturated Polyester as resin. In VRTM, the resin in force to draw through the whole length and width of the mold by applying pressure which was controlled through the vacuum pump attached with the portable setup. A number of blades have been fabricated to illustrate the feasibility and the application of this manufacturing method. This portable setup of VRTM has numerous cost advantages over traditional methods due to lower tooling costs, potential for room temperature processing and scalability for large structures.

Keywords: VRTM, Manufacturing, Wind Turbine Blade, Vacuum Pump.

1 Introduction

The blades of the wind turbine blades are supposed to continuously rotate under the cyclic action of wind and gravity of the structure. The life of the blades are generally designed for 15 to 20 years with the primarily required of high stiffness, low weight and high fatigue life. Several materials are available in nature and synthetically been manufactured including metals, plastics, wood, fibers and resins.
Aluminum blades are appeared first when the domestic wind power industry exploded. It offers many advantages like highly precision in dimension, improved strength and rigidity, better shear strength, not affected by UV light, recyclable and good weather stability but they are relatively heavy and costly. Wood is another readily available and inexpensive material but it requires a good shaping skills. In addition it is extremely susceptible to weather, soaking of moisture making it brittle in the sun, even it is not resilient under lateral stresses, and heavy wind can snap it without any difficulty. PVC (Polyvinyl Chloride) is another do-it-yourself choice available of turbine builders.

The advantage of this material is to consume less time in shaping, good synthetic appeal and far more temperature and humidity resilient than wood, but when exposed to sunlight forms tiny hairline crack on the surface. It is noticed that PVC materials are used where don't see much and direct expose to sunlight which is common when to place wind turbine for long period of time in most Asian countries.

Nowadays the most common method for producing wind turbine blades is using fiber impregnated with resin due to it narratives properties like lightweight, high tensile strength, fatigue strength and low cost. There are a group of fibers that have become commercially available like Carbon Fiber, Kevlar and Fiber Glass that offers superior strength and stiffness when compared to high performance metal. Even different resins are also available like Polyester based, vinylester, Phenolic and epoxy based resins. Based on the easily availability of materials, the selected combination is S- Glass Fiber Woven Roving Polyester based resin upon their better properties at higher temperature, stiffness, strength and toughness.

The next step is to select the manufacturing process that reduces the number of joined in composites through structural bonding and mechanical fastening with uniform mechanical properties along the surface. The VRTM (Vacuum assisted resin transfer molding) portable setup has been developed to fulfil the above stated output. VARTM is an advanced fabricating process for composite materials, performed by infusing liquid resin, which is sucked up by utilizing the differential pressure between the atmosphere and a vacuum, into laminated or woven fabric. To make the system cost effective, a portable setup of VRTM has been developed, to demonstrate, check the feasibility of the process and results, using home available vacuum cleaner suction pump. The blade is manufactured in two different halves through the profile of upper and lower shaped female molds which joined together through industrial glue.

The composite properties were studied via fabrication hand lay-up and VARI techniques using different layers and fiber orientation by Wisojodharmo and Roseno, concluded VRTM have better properties. [2]

Kong et al. [3] investigated the mechanical properties flax/vinyl ester natural fiber composite for eco-friendly structure using Vacuum Assisted Resin Transfer Molding (VARTM) manufacturing method. Through the structural testing, it is confirmed that the designed structure tank is acceptable for structural safety and stability using VRTM.

The application of VRTM process in composite manufacturing is presented by Brouwer et al [4] for large industrial application. With the support of two examples, they presented the successful development of large structure, i.e. 20m Rotor Blade and 16m long Hull for a Sailing Yacht.

Dong [5] developed a process model for the vacuum assisted resin transfer molding simulation by the response surface method. The factors like permeability, porosity and thickness of the fiber preform were studied on RTM mold filling time as response output. The significant process variables were identified and a quadratic regression equation developed to find the mold filling time.

2 EXPERIMENTAL WORKS

The materials employed in the fabrication of wind turbine blades are: Fiber glass WR 400, unsaturated Polyester resin, polystyrene block, gel coat, vacuum pump, and plastic sheets for vacuum bagging.

NREL S823 (un-symmetric airfoil) was chosen as an airfoil shape because for 1kw turbine it is recommended to use this shape which generates lift at low wind speed. The shape of blade to be generated is known in the form of chord and twist distribution, for convenience took ten values or section points along the 1.2m blade length. These 10 cross sectional airfoil templates is generated on software and paste on soft ply wood as shown in Figure 1.

These 10 templates of airfoil are placed on both the edges of Styrofoam (Polystyrene) block. Hot wire cutter is used to turn Polystyrene blocks into 10 components of female molds. The hot wire cutter moved slightly along the interface of a soft wood ply template, as long as the wire moves, polystyrene block gets the shape of desired profile molds. Furthermore the 10 Pieces of Polystyrene blocks were glued together to form a mold as shown in Figure 2. and plastic sheet was laid on the halves of mold to protect it from resin.

The surface of the blade is made from three layers of S-glass fiber with a layer orientation of 0/+45/0 sequence. These layers of fibers were wetted by small amount of Polyester resin with the help of rollers and then placed on wax coated female mold. A piece gauze wire is also placed on the mold to control the flowing pattern of the resin. This system of mold was inserted into the plastic

Figure 1. 10 Cross Sectional Airfoil Templates

sheet and sealed for vacuum bagging purpose as shown in Figure 3. The vacuum bag was contained ports for resin injection and for suction.

The representation of the whole portable system is shown in Figure 4 and 5, in which a single inlet for resin but seven injection points for uniform distribution of resin were also presented inside the vacuum. The vacuum suction points were also presented at different locations which are connected to the vacuum pump.

This Vacuum pump creates a suction of negative pressure. A Catch pot is connected between the suction line and the vacuum pump in order to prevent the pump from extra resin to enter in it. Now the process is carried out with this arranged portable setup when the matt is completely impregnated, removes the

Figure 2. Polystyrene blocks were glued together to form a mold

Figure 3

Figure 4. Portable VRTM setup with Vacuum Pump

Figure 5. Portable System with Resin Inlet and Suction Points

Figure 6. Fabricated Wind Turbine Blade

blade and allowed it to cure at the room temperature.

3 RESULTS

The completely fabricated and joined Horizontal axis wind turbine blade is shown in figure 6 and figure 7. The vacuum pressure is applied on a weave pattern of fiber glass, which completely impregnated the matt in 10s minutes. Trial-error method and adjustment of making blade reveals various perceptions for pre and post processing phases. Blade trimming from sharp edges of fibers and extra resin deposited on outside surfaces is an important finishing process. The dust from cutting fiber glass during grinding is toxic. A dust mask must be worn during this operation - ensure others around the blade do not inhale the dust. To improve the surface finish of the blade a layers of primer coating is applied on the entire surface.

Applications. A number of blades have been fabricated to illustrate the feasibility and the application of this manufacturing method. In future this process can be repeated with different high viscosity resin by increasing the suction pressure and study their effect on the strength of composite structure. The distribution of resin through different flow pattern are also in planned to reduce the process time.

1 CONCLUSION

A portable Vacuum-Assisted Resin Transfer Molding (VARTM) process has been successfully developed through which structural composite components can be manufactured. It is a clean and closed mold technique that allows for manufacturing of complex composite structures. VARTM has proven to be a cost-effective method for wind turbine blades and also for other newly.

ACKNOWLEDGEMENTS

The authors acknowledged the cooperation of Carpentry Shop of Mechanical Engineering Dept. NEDUET in carrying out the Process testing and the real experiments.

Figure 7. Fabricated Wind Turbine

REFERENCES

[1] M. S. Koefoed, Modeling and Simulation of the VARTM Process for Wind Turbine Blades, (Thesis) Institute of Mechanical Engineering Aalborg University, Denmark, 2003.

[2] L. A. Wisojodharmo, & S. Roseno, The Use of Vacuum Assisted Resin Infusion Process on the Manufacturing of Wind Blade Composites, Journal of Materials Science and Engineering, 2(1), 74-78, 2012.

[3] C. Kong, H. Park & J. Lee, Study on structural design and analysis of flax natural fiber composite tank manufactured by vacuum assisted resin transfer molding, Materials Letters, 130, 21-25, 2014.

[4] W. D. Brouwer & M. Labordus, Vacuum Injection Moulding for Large Structural Applications, Composites, 34, 551–558, 2003.

[5] C. J. Dong, Development of a process model for the vacuum assisted resin transfer molding simulation by the response surface method, Composites Part A: Applied Science and Manufacturing, 37(9), 1316-1324, 2006.

[6] J. Merotte, P. Simacek, & S. G. Advani, Resin flow analysis with fiber preform deformation in through thickness direction during Compression Resin Transfer Molding, Composites Part A: Applied Science and Manufacturing, 41(7), 881-887, 2010.

[7] S. Laurenzi, A. Casini, & D. Pocci, Design and fabrication of a helicopter unitized structure using resin transfer moulding. Composites Part A: Applied Science and Manufacturing, 67, 221-232, 2014.

[8] G. W. Lee, N. J. Lee, J. Jang, K. J. Lee, & J. D. Nam, Effect of surface modification on the resin transfer moulding (RTM) of glass fibre/unsaturated polyester composites, Composite science and technology, 62(1), 9-16, 2002.

[9] D. Bender, J. Schuster, & D. Heider, Flow rate control during vacuum-assisted resin transfer molding (VARTM) processing, Composites Science and Technology, 66(13), 2265-2271, 2006.

[10] Jon Dana Skramstad, Evaluation of hand layup and resin transfer molding in Composite wind turbineblade manufacturing, (Thesis) Montana State University-Bozeman, Bozeman, Montana, 1999.

Energy Scenarios of Pakistan and Conservation Measures

Engr. Muhammad Saghir Khan

Abstract:
Pakistan will continue to face chronic power shortages for the next year or more, despite aggressive pledges and plans announced by government officials and aid promised by various foreign organizations and diplomats. System inefficiencies prevent plans of the international organizations from being effectively implemented, while the poor fiscal position aggravates the situation as private producers are discouraged from increasing investment given the lack of promptness in payment. Hydro power and renewable energy sources remain as alternatives that states struggle to tap on due to the high capital outlays required. The demand for energy keeps rising due to economical and social development with regards to building sectors, which various adverse impacts on the environment.

The building sectors in developing countries consume more than 45 % of energy as compared to other sectors. Therefore now it is required to minimize the energy consumption in building sectors by introducing energy efficient strategies to control the demand side management. In Pakistan the building sector consume almost 57- 59 % of the electricity produced. The foregoing article is discussing the energy conservation measures in building sectors. Energy Services Companies represent an effective tool to implement energy conservation projects. They provide the know-how and may be finance for implementations in beneficiary enterprises.

The energy industry went through an evolution process in the past two decades. Once the utilities incentive programs were eliminated, other major companies, including manufactures, contractors and utilities companies, emerged to sell and implement energy savings projects. These organizations offered third party financing and "Performance based" projects that guaranteed the expected savings through contractual agreements with the customer. This paper will discuss the evolution stages of the energy industry. History and current status of Energy Services Companies (ESCOs) and markets of the energy industry, future evolutions and the potential of the industry in the united states and an insight of the Energy Services Company (ESCo) opportunities and challenges in Pakistan.

Although energy services companies have proved their effectiveness in many countries, however this industry will be new to the Pakistan market.
The Energy Efficiency Improvement Organization (EEIO) under the Govt. platform says as Enercon with dedicated components to

provide support, to this industry.

Support is needed to provide through different programs including, energy audit program, trading and capacity building, loan guarantee program to facilitate access to finance and technical support. EEIO support to ESCOs will pass through different phases to established model of ESCOs in Pakistan, based on different backgrounds and working scopes.

Regardless with this kind of institutional support, we all realized that this industry will face more challenges due to low awareness, policy of energy subsidy, and unavailability of specialized agency to resolve disputes which arise due to new this business.

To overcome these obstacles, EEIO with help of Enercon or other Govt. authority should establish Energy Efficiency Law which in many parts of it will offer a boost to this industry through tackling the after mentioned obstacles. Furthermore EEIO is to open new business opportunities to these companies through an initiative for Energy Efficiency in Governmental buildings, propose new scope for co-generation projects and developing interruptible power contracts.

Introduction:

Pakistan will continue to face chronic power shortages for the next year or more, despite aggressive pledges and plans announced by government officials and aid promised by various foreign organizations and diplomats. System inefficiencies prevent plans of the international organizations from being effectively implemented, while the poor fiscal position aggravates the situation as private producers are discouraged from increasing investment given the lack of promptness in payment. Hydro power and renewable energy sources remain as alternatives that states struggle to tap on due to the high capital outlays required.

Permanent resolutions and solutions to the power shortage remain out of sight for Pakistan as load shedding across the country remains on the rise. The shortfall has escalated further as faulty generators, lack of fuel (oil and gas) and low levels of rain compounded the situation. Poor performance from existing generating assets, the lack investment in generating capacity, power thefts and an inefficient grid remain obstacles to the government's aim.

It is now well established that End-use Efficiency and Demand-side Management (DSM) provide flexible, low risk and cost effective substitution to traditional supply side management options for meeting growth in less predictable demand for energy. As such significant interest and effort has been invested into promoting and implementing energy efficiency and DSM programs and strategies.

The Demand Side Management (DSM) refers to a programs made by the electric and gas utilities to modify customer energy use patterns. The DSM programs started in U.S. in 1970 in response to growing concerns about dependence on foreign oil, environmental concerns of pollution from electricity generation, and concerns about the lack of electrical transmission and generation capacities to meet to growing demand.

DSM programs grew rapidly in the late 1980s as state regulators permitted utilities to offer incentives to customers to implement energy efficiency measures DSM programs reached 27$ Billions of utility spending in 1993 and 1994, which is equivalent to 4% of U.S. utility revenue. The same period of time witnessed the development of Energy Services Companies (ESCOs), which are companies that specialized in delivering energy efficiency products and services.

Energy Services Companies (ESCOs) have led this field by offering performance based contractual agreements on energy efficiency projects. In its basic form the ESCO conducts simple and detailed audits of customer premises to estimate energy savings potential. The ESCO then produces detailed design of the project and takes responsibility for installing and maintaining the equipment for the duration of the project. Generally a third party financier, in some cases the banker of the customer, provides required funds for the implementation of the project as a loan. The loan as well as the remuneration for ESCO the services is paid through energy savings, thereby creating a win-win Situations for all parties involved.

This model is operating successfully in economies where ESCO model is well established and ESCO Industry has reached maturity. However, experience has shown that external intervention is required to create enabling market conditions for ESCO sector to flourish to the point of maturity, especially in Economies where the concepts of either or both energy efficiency and commercialization of energy Efficiency services are relatively new. Such interventions may include capacity building of ESCOs, Education awareness campaigns, standards and regulations, availability of funds for ESCO projects etc.

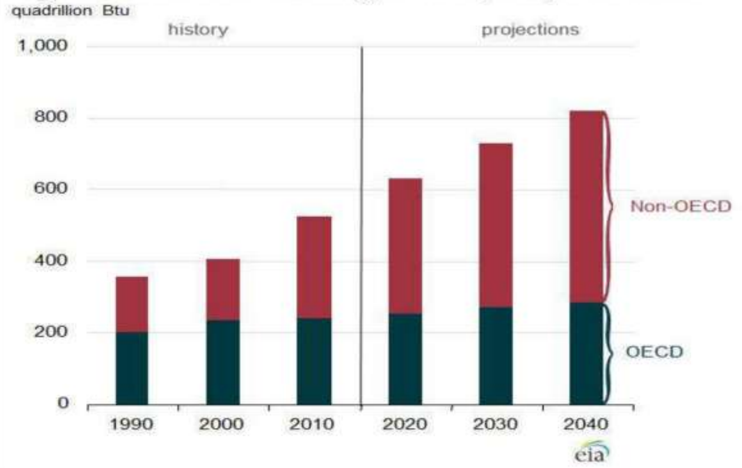
This paper discusses various aspects that may critically affect the development of ESCO sector in a relatively raw environment. Such aspects are discussed from the perspective of an ESCO, the enabling bodies, and the fund providers.

Primary Energy Consumption Scenarios of Pakistan

First all I would like give little brief on World energy consumption scenario which is growing at an alarming rate, due to a number of factors including, but not limited to; advancement in technology, population growth, and increased personal motorization. Furthermore, such growth has been affected by the oscillations in world oil prices.

According to International Energy Outlook.2013 reference, world energy consumption is projected to increase by 56 % from 2010 to 2040. The strongest growth in energy consumption will take place among the developing nations of the world. Gross domestic product (GDP) in developing Asia is expected to expand affecting the demand for energy in developing Asia to double. More than 85 percent of the increase in global energy demand from 2010 to 2040 occurs among the developing nations outside the Organization for Economic Cooperation and Development (non-OECD), driven by strong economic growth and expanding populations. In contrast, OECD member countries are, for the most part, already more mature energy consumers, with slower anticipated economic growth and little or no anticipated population growth.

Figure 12. World total energy consumption, 1990-2040



Region	2010	2015	2020	2025	2030	2035	2040	Average annual percent change 2010-2040
OECD	242	244	255	263	269	276	285	0.5
Americas	120	121	126	130	133	137	144	0.6
Europe	82	82	85	89	91	93	95	0.5
Asia	40	41	43	44	45	46	46	0.5
Non-OECD	282	328	375	418	460	501	535	2.2
Europe and Eurasia	47	50	53	57	61	65	67	1.2
Asia	159	194	230	262	290	317	337	2.5
Middle East	28	33	37	39	43	46	49	1.9
Africa	19	20	22	24	27	31	35	2.1
Central and South America	29	31	33	35	39	42	47	1.6
World	524	572	630	680	729	777	820	1.5

Source: History: EIA, International Energy Statistics database (as of November 2012), Projections: EIA, World Energy Projection System Plus (2013)

Table 1. World energy consumption by country grouping, 2010-2040 quadrillion Btu

In contrast to the developing world, slower growth in energy demand is projected for the industrialized world. This is due to that the industrialized world is considered as mature energy consumers with slower population growth. Other factors are movement away from energy-intensive manufacturing to service industries result, and projected gains in energy efficiency as old, inefficient equipment is replaced.

The fastest growing source of primary energy is natural gas. Over the 2001-2025 forecast periods, consumption of natural gas is projected to increase by 67 %. Concerns about the long-term ability of natural gas producers to bring sufficient resources to market at prices competitive with those of other fuels is one of the limitations of using natural gas

.

The Pakistan's Energy sector is in a state of crisis and over the past few years has negatively impacted the social and economic development of the country.

Primary energy consumption in Pakistan has grown by almost 80% over the past 15 years, from 34 million tons oil equivalent (TOEs) in 1994/95 to 61 million TOEs in 2009/10 and has supported an average GDP growth rate in the country of about 4.5% per annum. However since 2006/07 energy supply has been unable to meet the country's demand leading to Shortages. Meanwhile per capita energy consumption in Pakistan at under 0.5 TOEs/capita remains only one-third of world average.

Indigenous natural gas is the largest source of energy supply in Pakistan contributing 27.7 million TOEs (45.4%) in 2009/10, followed by oil products, mainly imports, at 21.3 million TOEs (34.9%), hydel power at 7.5 million TOEs (12.3%), coal, mainly imports, at 3.7 million TOEs (6.1%) and nuclear power at 0.8 million TOEs (1.3%).Cconsumption of indigenous natural gas has grown rapidly in all sectors of the economy (residential, commercial, industrial, transport and power) over the past 15 years, driven by growing availability of gas and a low, government-controlled gas price as compared with alternate fuel prices.

As a result, Pakistan has developed a vast natural gas transmission and distribution network across the country. However Pakistan's indigenous natural gas reserves are declining and a low gas price has become significant disincentive in attracting new gas supplies, either through increased domestic exploration activities or via imports of liquefied natural gas (LNG) or regional gas pipeline imports.

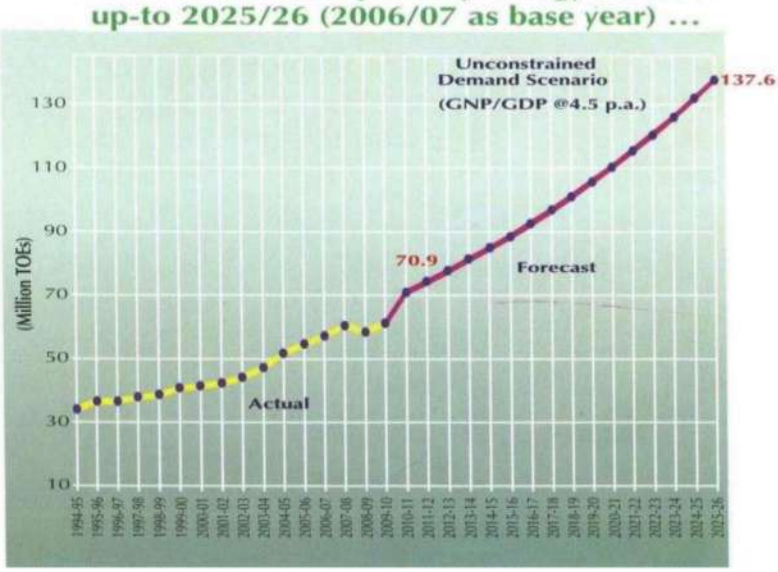
It is also unlikely that Pakistan will be able to substantially develop its other indigenous energy sources of Hydel power and coal by 2025/26 under current policies, and the energy import requirements of the country may grow from the present 30% to over 75% of the energy mix by 2025/26 costing over $ 50 billion per annum in foreign exchange.

This Pakistan Energy Outlook document identifies a set of energy **"Blueprints"** which, if implemented, could allow the energy sector in Pakistan to thrive and grow and become the engine for the social and economic development of the country, allowing accelerated GDP growth rates. As with all reform processes, the "Blueprints" will require significant political will to execute and it is hoped that the present and succeeding governments in Pakistan will rise to the occasion. The energy conservations and demand side management will be another option to look into to reduce Primary Energy demand for power Generation.

To achieve 4.5% p.a GDP growth over the next15 years, primary energy demand will double ...

Primary Energy Demand	2010 – 11 (mn TOEs)	2025-26 (mn TOEs)	% growth
1. Residential & Commercial	7.08	13.60	92.1%
2. Industrial	21.40	41.95	96.0%
3. Transport, Agriculture, GOP	13.45	24.30	80.7%
4. Power Generation	29.03	57.77	99.0%
Total	70.98	137.64	93.9%

Pakistan: Forecast primary energy demand up-to 2025/26 (2006/07 as base year) ...



Pakistan's energy supply, driven by indigenous natural gas, has supported an average GDP growth rate of approx. 4.5% per annum over the past 15 years – the Scenario choices for the future are:

In Business-as-usual scenario of Pakistan from year, 2010-11 to 2025-26) with indigenous natural gas supply expected to decline in the near future, "business-as-usual" polices will be unable to meet Pakistan's energy demand for the next 15 years even for a 4.5% per annum GDP growth rate .

Pakistan Power Sector Scenario

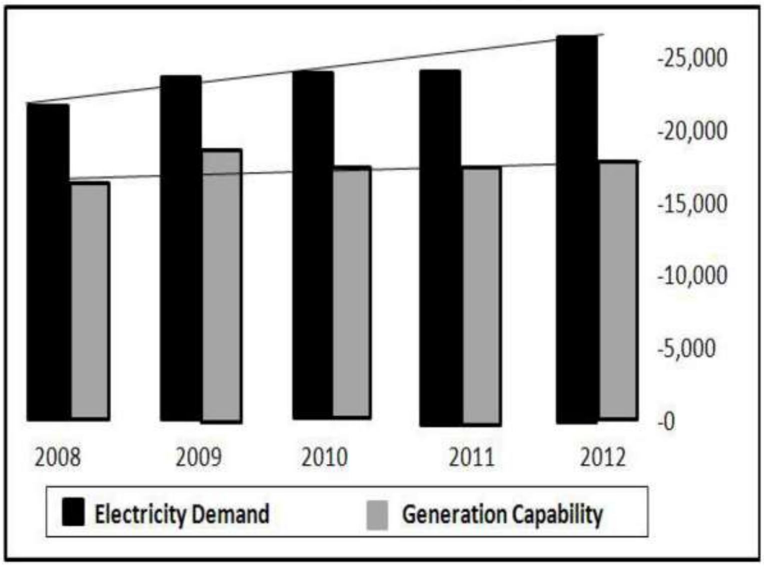
The government-controlled power sector in Pakistan, one of the largest consumers of primary energy, is facing growing problems due to an unrealistic power tariff, high inefficiencies, low payment recovery and the inability of the government to manage its subsidies mechanism. This has led to a serious "circular dap t' issue which is becoming a barrier for future energy sector investment. Pakistan will continue to face chronic power shortages for the next year or more, despite aggressive pledges and plans announced by government officials and aid promised by various foreign organizations and diplomats. System inefficiencies prevent plans of the international organizations from being effectively implemented, while the poor fiscal position aggravates the situation as private producers are discouraged from increasing investment given the lack of promptness in payment. Hydro power and renewable energy sources remain as alternatives that states struggle to tap on due to the high capital outlays required.

Permanent resolutions and solutions to the power shortage remain out of sight for Pakistan as load shedding across the country remains on the rise. The shortfall has escalated further as faulty generators, lack of fuel (oil and gas) and low levels of rain compounded the situation.

The gap between electricity demand and generation capability in Pakistan has widened over the last decade, with the country experiencing a shortfall of approximately **6,500MW** of generation capability in 2012, according to NEPRA.

This deficit is caused primarily by a lack of fuel for thermal generation, and realizing the country's renewable energy resources (which do not require fuel) would help the country to increase its effective generation capability, however following chart indicates the total growing electricity deficit which need to be fulfilled.

Pakistan - Electricity Demand and Generation Capability, MW



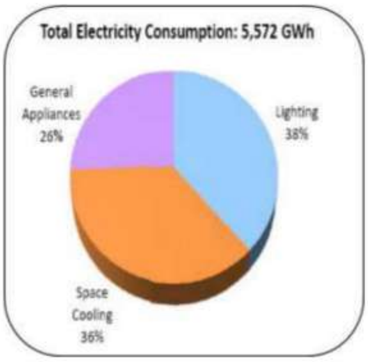
In recent development, On August 8, Pakistan's government has announced that 14 power projects in the country had obtained funding approval from the Chinese government. The Chinese government agreed to provide loans to cover the project costs (up to 85% of the total cost) and help in the development of these projects. We believe that Pakistan's power sector is set to benefit tremendously from this and has resulted in a material upward revision for our thermal, hydropower, and solar capacity forecasts. We now expect thermal capacity in Pakistan to grow by 4.5% per annum (up from 0.8% previously), and total capacity to grow by 5.4% per annum (up from 3.3% previously).

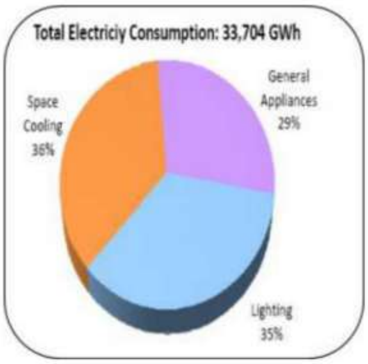
Despite these developments, the Pakistan power sector remains in a dire state, despite the government's efforts to address power shortages. The lack of transmission and distribution infrastructure, in particular, has had extremely devastating effects on the sector and which has seen that private sector players move towards captive (or off-grid) generation in order to bypass grid limitations, In order to avoid such situations this has necessitate, we should look for the Energy Conservations in all sectors and particularly to Building Sector which is consuming almost 45% of power consumption compare to others power consumers , therefore our further discussions will be on energy conservation measures in building envelop construction materials and the associated Building Energy Systems.

POWER CONSUMPTION IN BUILDINGS AND INDUSTRY.

The demand for energy keeps rising due to economical and social development with regards to building sectors Industry which various adverse impacts on the environment, which are responsible for the present climate change in the form of global warming.

The building sectors in developing countries consume more than 45 % of energy as compared to other sectors. Therefore now it is required to minimize the energy consumption in building sectors by introducing energy efficient strategies to control the demand side management. In Pakistan the building sector consume almost 57- 59 % of the electricity produced. The foregoing article is discussing the energy conservation measures in building sectors.





Total Power consumption in Buildings and Industry in year 2009.

ENERGY CONSERVATION MEASURES IN BUILDING SYSTEMS.

Today, the foremost task of building energy conservation is to readopt the technique that has been passed down through thousands of years of human ingenuity. The goal is to couple these basic technologies with modern materials to achieve substantially heightened insulation performance, through the development of advanced ventilation technologies. In other areas, such as the development of energy efficient power generation, heating and cooling technologies and utilization of renewable energy, they are merely for show. In the past, technology supremacies exaggerated the efficiency potentials of energy facilities, and propagated the impractical expectations of renewable energies. As a result, people continued to build high-energy consuming endlessly delayed and unheard. Hence, the orientation of technology polices shall have its focus the reduction of the building's energy consumption (passive technology), rather than the increase of power generation, heating and cooling efficiency (active technology), as the energy saving potential of building itself is as high as 80% to 100%. Also, a priority shall be given to the adoption of straightforward technologies, common materials and ordinary workers, rather than cutting edge technologies, expensive materials and rare specialists. Only this way can building energy conservation be popularized. Considering that more than 95% of buildings around the world are not energy efficient buildings. Without popularization, there can be no action.

THE ENERGY-SAVING GOAL

In the past 30 years, many countries in the world have established their own standards on building energy conservation. Among which German-speaking countries in Europe are most enthusiastic. In Germany, between 1997 and 2007, building energy saving standards have undergone 5 revisions, each time with highly improved energy saving targets. As a result, the target has increased by 80% in 30 years. If this had been any other field, this would have represented a big success. But in the building industry, this is a huge failure – Buildings facilities which are used for a significant amount of time. If a proper goal were set 30 years ago, there would be no need to retrofit these buildings, avoiding wasteful investment and disruption to citizens. To avoid such counter-productivity, each country should be determined to work out a one-step achievable goal of building energy conservation.

1) Thermal dissipation-utilizing thermal insulation in hot regions

In South Asia, and the Middle East, where more than half of the world's population live, few buildings are ever insulated. The result is that people which cooling systems consume too much, and people with cooling system suffer.

The average heat emission of person is roughly 150 W, so 0.3KW cooling is enough for a 20m²room with two people. But the normal practice is to use 1.8 to 2.7KW (i.e. 1 to 1.5HP heat) cooling. That is the reason why the minimum capacity of an air conditioner in the world is no less than 1.8KW.

In hot season, buildings insulation can save 3 to 6 time air conditioning. Even room without air conditioner, the temperature during the day is close to the outdoor temperature at midnight.

2) Glazing-using small triple-glazed plastic-framed windows

Few people realize that windows sometime play a more important role than walls do in building energy conservation.

Contemporary large size windows and glass facades, which are common today, reflect people's desire for stimulation and status. They are neither good for comfort levels, nor healthy for human beings. Research reveals that staying is an overly lit room for an extended period may cause sight deterioration, aggressiveness, anxiety and abnormal heart beats. From the point of view of health and comfort, a 1.2 to 2m² window would be appropriate for a 20m² room. Hence, some countries should modify their lighting standard.

From the perspective of building energy conversation, large windows are even more detrimental. A triple-glazed plastic window with high thermal insulation performance consumes 12 times more energy compared to 300mm foam insulated to all of the same area.

Another reason that led to the widespread popularity of large window is that they give people access to sunshine in winter and cooling breeze in summer, additionally saving electricity for lighting. Although that is true, the window should be equipped with move able heat insulation shades are thick down-feather curtains. If the windows are not in use, they should be covered. Otherwise the heat loss would steel be 2 to 4 times greater.

The heat transfer coefficient of currently prevent aluminum window frames is 23 times higher than that of plastic frames. So in countries with high levels of energy saving consciousness such as Germany and Austria, the use of plastic frame has increased rapidly and is now above 50%. Even thermal bridge aluminum frames or seldom used in these countries, because only half fame was bridged. Plastic frames are improving in appearance and durability. In addition, the heat transfer coefficient of the prevalent double-glazed window is 1.6 times that of the triple-glazed window. Europe and northern China is now popularizing triple-glazed windows, are even quadruple-glazed window.

3) Solar shading devices-using external shading devices

In summer, people tend to think that as long as the curtains are drawn, sun radiation will be blocked. But in fact, only the sunrays are kept out, while the heat is trapped within the confines of the space. It is only when we shade the window from outside that we can prevent the heat from entering the room. Using Low-E window is not sufficient. It can only improve the shading effect by 1/3 but is far more expansive. Since ancient times, the Europeans have been shading the windows from the outside. Other areas in the world use internal shading. This is one of the reason why European countries. Consume less energy for cooling than other countries do.

Furthermore, in hot season installing the wall thermal insulation on the east, South and West wall can reduce over 70% of heat gain. With additional thermal insulation, solar shading can more effectively lower the temperature.

The sun is the enemy of cold air. Thus, a 2m² window can take in about 1.5kWh of heat under direct sunshine, which roughly equates to the heat emissions of 15 adults in a room.

4) Ventilation- utilizing fresh air supply and exhaust air heat recovery

People are often accustomed to opening their windows for purposes of creating ventilation. Windows are usually kept closed when it is too cold or when air conditioning unit is switched on. The modern medicine has proven that poor ventilation may cause serious health issues, such as lack of oxygen and chemical gas accumulation such as formaldehyde and benzene, which can cause many diseases. Including birth deformities, leukemia, respiratory diseases, heart diseases and cancers.

Our Consensuses are 1) good ventilation is a prerequisite for building energy conservation, which cannot be neglected at the cost of our health. 2) when the temperature difference is 3 °C, ventilation goes heat exchange, that is, to use the exhaust air to heat or cool the inlet fresh air, which could reduce 70 to 90% of the ventilation heat loss; 3) try to utilize natural ventilation (when outdoor air quality meets health standard) during mild climates.

In contrast, electricity wastage in ventilation systems in hotels, office buildings and large public buildings is very serious. Largely because of lack of inverter controls and high filter resistance in unclean, blocked and dirty filters. Here, ventilation electricity of per cubic meter can be as high as 2 to 5 W. However, in a reasonable system the ventilation electricity per cubic meter should be kept within 0.3 to 0.7 W. for a 50,000 m^2 medium –sized building, ventilation electricity amount to 2 to 5 million kWh yearly, this wastage is rarely noticed.

5) Lighting- using energy efficient light bulbs

Lighting-related energy wastage is widely known, but extremely overlooked. Government should take the following measures: 1) Drawing from the Australian experience to phase out incandescent bulbs in next 2 to 3 years, because lighting efficiency of incandescent bulb is only 5%, while energy efficient bulbs is 25% to 80%; 2) set forth explicit illuminance standards—bulbs within the range of 150 lux to 200 Lux(with a power consumption rate of as low as 2W to 3W/m^2) are found to be most beneficial to eyesight; 3) use two-way switches in a room and sensor automated switches for areas where people visit infrequently, e.g. corridors and bathrooms; 4) use natural lighting when possible, keep out direct sunshine, otherwise energy consumption from cooling will be 2 to 5 times higher than that is saved on lighting.

Lighting wastage is very significant in terms of energy consumption. A 60W incandescent bulb consumes an additional 50W of electricity and 50W of cooling, as compared with an energy efficient bulb of same illuminance, which is equivalent to consuming 250W more primary energy equates to 30kg of oil every air. Lighting is therefore not trivial and should not be overlooked.

6) Renewable Energies

Pakistan appears keen on working with international agencies to develop renewable energy as it is seeking to alleviate power shortages and reduce its reliance on costly fuel imports. Oil- and gas-fired generation accounts for over 60% of the country's total electricity mix, and higher fuel import prices have led to fuel shortages and rising costs. According to the government, Pakistan continues to experience an energy shortage of 4,000 megawatts (MW). Nameplate generating capacity in the country currently stands at 20,000MW, but Pakistan's state utility announced that they are only able to supply 13,000MW due to a lack of affordable fuel. More Energy Imports Due To Reliance on Oil and Gas

Renewable energy appears to be an appealing solution. Not only does it not involve costly fuel imports, but the country theoretically has significant potential for renewable energy generation as Pakistan had the world's best insulation with proven power generation of 4-5 kilowatt hours per meter square and more than 3,000 hours of sunshine throughout the year.

Energy Efficiency Market Of Pakistan With Its Potentials And Barriars:

The Energy Efficiency market size is estimated at 1.5 billion U.S$, with their respective breakdown of the market size by technology. Cogeneration, process controls and power factor improvement have the highest opportunities. Considering the number of potentials implementations, power factor improvement and lighting are the highest. The industrial sector accounts for 95% of the total market opportunities, while the commercial sector accounts for only 5%, regardless the market potentials, the market suffers from many negative forces.

Although many efforts have been made for improving awareness, further efforts are still needed especially at the decision making level. Lack of operating, calibrated energy measuring instruments and absence of forms and records for energy consumption add to awareness problem on the plant level. Absence of national codes and standards for energy consumption as well as energy bench marking for energy utilization efficiency in industrial processes, limits the market. On the other hand there is no incentive or rebate policy for energy conservation projects.
Regarding the energy prices, they have been increasing drastically, oil and gas respectively increased by 30% and evaluated according to the exchange rate of the Pak rupees against the U.S$.
Although the aforementioned increases in prices improve the attractiveness of the Energy Efficiency projects. Especially for thermal process application, as our natural resource for hydrel power generation is diminishing. The distortion between electricity and fuel prices has been increased. This has a negative effect on the financial attractiveness of the cogeneration projects.

Break down of Energy Efficiency market in Pakistan by technology.

Regarding the economical barriers, the Pak rupees has been subjected to a period of instability over the past many years and in further as well is expected, which may affect for the attractiveness of energy conservation projects which rely sizably on imported items.
The legal structure need to be established to face and risk free for asset-backing lending. Financial institutions are lacking knowledge and experience regarding efficiency projects.

All these factors limit the amount of debt and equity ratio for energy savings projects of one to one. The cost of finance is high. The average interest rate range between 12 to 15% limited resources are available for medium and long-term finance. However it is important to mention that many donors funded programs are available. The legal system suffers from complex and slow process for resolving legal disputes.

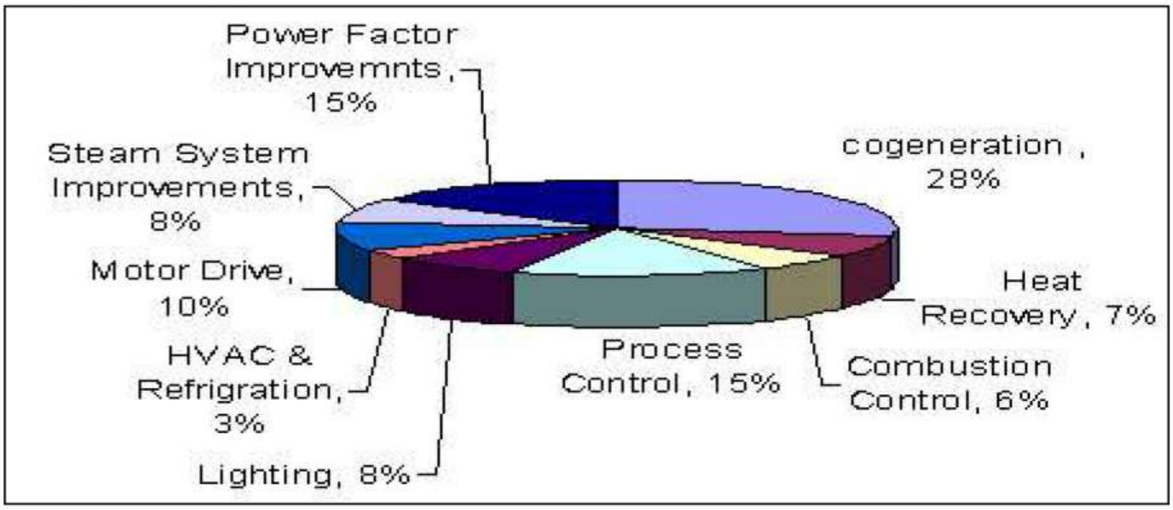
Also there is a lack of experience in resolving disputes, which may arise in some cases when the Measurements and Verification Protocols (MVP) are considered for evaluating the savings.

EFFORTS OF "ENERGY EFFICIENCY IMPROVEMENT ORGANIZATION" (EEIO)

There is need to established the Energy Efficiency Improvement Organization (EEIO) which is to be executed through governmental organization, such as Enercon as the project will consists of three components including loss reduction on national grid and demand side management component, market support for Energy Efficiency business, energy codes, standards components and cogeneration component.

The project approach is to establish mechanisms which can ensure sustainable energy conservation activities beyond the life time of the project. EEIO to adopt the Energy Services Company "ESCO" approach as tool to provide energy efficiency know-low and enable finance to the customers.

Although several variations of the ESCO models are available as shown in Table-3, EEIO has to adopt a specific



Sr.No	ESCO Model	Model Description
1	Full Service ESCO	The ESCO provides a comprehensive service including energy audit, project design, project implementation, operation and maintenance and finance through a shared saving performance contract
2	ESCO with Variable Term Contracts	Similar to above except the contract terms can be varied based on the actual savings. In case if the expected savings does not achieved the targeted values, the contract can be extended till the ESCO recovers it agreed payments. Also it could include what is called a "first out" model, where the ESCO takes all the energy savings until it has received its agreed payments.
3	ESCO with Third Party Finance	The ESCO provides a technical service without finance. The customer may provide finance or the ESCO may arrange for facilitating finance by a third party. The ESCO provides guarantee that the energy savings will cover the debt services payments. This is known as performance contracts with guaranteed savings.
4	End-Use Out Sourcing (Energy Management Contract)	The ESCO provides only operation and maintenance services at an agreed price. Cost of all equipment, upgrade, repairs, etc. are borne by the ESCO, but the ownership of the equipment remains with the customers. This is usually used in running the customers utilities such as power generation, steam generation heating/cooling, where the customer pays an agreed price for the received units (KWh, tons of steam, etc).
5	Equipment Supplier Credit	The ESCO provide full technical service. It verifies that the performance and energy savings matches the expectations. Payment can be either on lump-sum basses or on installments based on the expected savings. Ownership of the equipment is transferred to the customer immediately.
6	Equipment Leasing	Similar the supplier credit except the ESCO holds the ownership of the equipment till the end of the leasing contract. At the end of the contract the customer has three choices, renewing the contract, owns the equipment at its residual value or the ESCO takes the equipment out.
7	Technical Consultant with Performance Based Payment	ESCO conducts an audit and assist in project implementation. The ESCO and the customer agree on performance based fee, which could include penalties for lower savings and bonuses for higher savings.
8	Technical Consultant with fixed Payment	The ESCO conducts an audit, designs the project and either assists the customer to implement the project or simply advises the customer for a fixed lump-sum fee.

model at the beginning to meet the local demand.

To introduce the ESCOs, to the market, EEIO has to establish a partially financed energy audits program which should includes energy audits in different industrial and commercial enterprises. EEIO provides technical support to the ESCOs as well as expensive measuring instruments including power analyzers, gas analyzers, flow, temperature and light measuring instruments as well as loggers.

Parallel to the audits program EEIO has to provide capacity building to the ESCOs through training on energy auditing, energy efficiency technologies, projects economical evaluation and feasibility studies, financing energy efficiency projects and evaluation of project risks. EEIO issue Pakistan Measurements and Verification Protocol (MVP) to verify energy savings, which is necessary for performance contracting.

Although the ESCOs will be responsible to identify their customers, EEIO has to set general guide lines for customer selection including criteria such as the facility should not operate at less then

60% of its capacity and management commitment.

Initiative For Energy Efficiency In Governmetal And Public Buildings:

Another contribution by EEIO to support ESCO business came through its initiative to create an implementation mechanism for the government initiative to conserve energy in governmental building and public services. This initiative includes developing a mechanism which enables governmental agencies to request energy efficiency service through performance guaranteed contracts. To facilitate this EEIO is to standardizing this mechanism through developing the necessary procedures and formats as well as verification protocol, which are necessary for the bidding document. Also it should develop a standard performance contract, evaluation criteria and solicitation process.

Eeio Longterm Mechanisms:

Improving the energy efficiency business environment represents should be one of the main targets of EEIO In addition to the aforementioned short terms activities, EEIO to create a long term mechanisms which can ensure the sustainability of the business. Regarding these mechanisms which should include, developing a draft for energy efficiency law and the development of demand side management scheme which relies on interruptible power contracts.

Regarding the energy efficiency law in addition to many measures include in the law, some measures have direct impact on boosting the energy efficiency business, these measures include:-

a. Making energy auditing in industrial and commercial enterprises mandatory every three years.
b. Developing energy efficiency bench marking system based on the local practice for different industrial and commercial sectors.
c. Requesting all energy providers (i.e. electricity and fuel) to allocate 1% of their revenue for the promotion of energy conservation concept as well as public awareness.

Establishing a mechanism through Govt. agency to implement as well as enforce the law, during the approval of any project for executions.

The Energy Efficiency Improvements Organization (EEIO) project will contribute to create an energy service industry in Pakistan through in many cases including capacity building, enabling financially supported energy audits, and easing access to finance. However the demand still has to be created for real market development.

This is attributed to many factors including the national economy and the market conditions as well as public awareness to overcome these barriers EEIO to develop different mechanisms to activate the market such as developing and implement ting mechanisms for the governmented initiative for energy conservation in public building.

On the long terms level EEIO to adopt as initiative for Pakistan to have its energy efficiency law it is believed that these measures will boost the energy efficiency business to a new horizon.

CONCLUSION:

- Formation of Energy Efficiency Improvement Organization (EEIO) will contribute to create an energy service industry in Pakistan through many measures including capacity building, support energy audits etc.
- On the long term level EEIO to adopt an initiative for Pakistan to have its energy efficiency law as well as the promotion of interruptible power contracts.
- Demand side management can help in resolving energy issues in Pakistan faster than supply side.
- Challenges and opportunities that will face in Pakistan include low efficiency building system design, financing and lack of awareness.

References:

1. Energy Efficiency business profile.
2. Monthly Energy Up Date Magazine Karachi, Pakistan.
3. "Key world energy statistics" International Energy agency, 2004.
4. Energy Efficiency improvements, project documents 2005.
5. Hydrocarbon Development Institute of Pakistan, Energy Update 2007.
6. Pakistan Energy Year Book.
7. World Fact Book 2004.
8. World Development Indicators 2010, World Bank Report.
9. Energy Year Book – Hydrocarbon Development Institute of Pakistan (HDIP) & Pakistan Oil Report – Oil Companies Advisory Committee.
10. Power System Statistics & Economic Survey for Electricity Connection – Pakistan Energy Year Book for Gas Connections.
11. BMI Middle East and Africa Power and Renewables Insight January 2014.

Foto News

5th International Mechanical Engineering Congress 9th-10th May 2015 held at Karachi





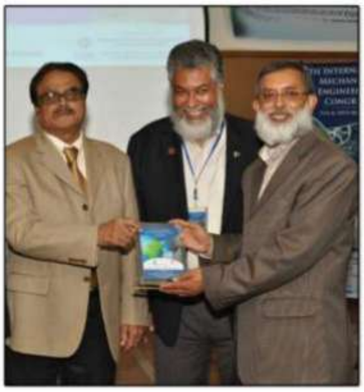






Foto News

7th International Civil Engineering Congress 12-13 June 2015held at Karachi

Chemical Looping Combustion (CLC)

A Novel Technology For Energy Production From The Coal With Inherent Co2 Capture

Engr. M Younas
m.younas@uetpeshawar.edu.pk

Engr. I. K. Swati

Engr. S. Gul

Abstract
The current work investigates the theoretical behaviour of a CLC operated packed bed reactor for the combustion of syngas from coal gasification plant with Fe_2O_3 (Hematite) as oxygen carrier material. The simulation was performed for the I-D transient model of the packed bed reactor for oxidation and reduction cycle. The system is composed of two cycles, oxidation and reduction, whereas the flue gas from the reduction cycle contains CO_2 and H_2O and the flue gas from the oxidation cycle contains only N_2 and some un-reacted O_2. Thus, CO_2 and H_2O are inherently separated from the rest of the flue gases, and no major energy is required for this separation. Three different options were considered for the study as the base cases depending upon the weight fraction of Fe_2O_3, temperature of the feed gas and bed and flow direction of the feed gas for the succeeding cycle. One reactor is used with switching the feed gas over air or syngas for the oxidation and reduction cycles, respectively. The results showed that reverse flow CLC process achieves the maximum efficiency producing high temperature exit gas stream during the oxidation and the reduction cycles with no fuel slip.

Keywords: Chemical looping combustion (CLC); packed bed reactor; modelling and simulation; syngas; hematite.

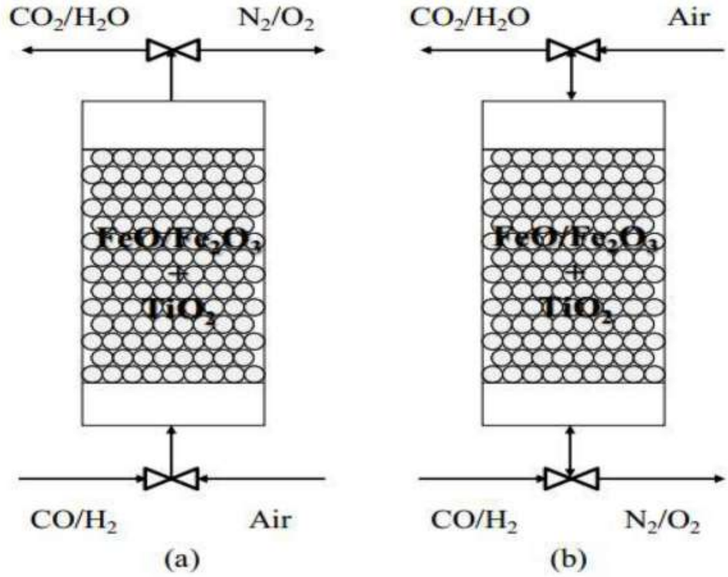
1 Introduction

CO_2 is the most prevalent greenhouse gas which is the main contributor to global warming. Power generation via fossil fuel combustion with effective CO_2 capture appears to become a key contributor to the energy supply in the foreseeable future. Most of CO_2 capture technologies have high energy penalty for the separation of CO_2 from the rest of the flue gas components, which will result in a price of the energy because of the cost for CO_2 capture [1, 2]. Chemical-looping combustion for fossil fuel combustion, with inherent capture of CO_2. The produced gases, CO_2 and H_2O, leave the system as a separate stream from the exit of the fuel reactor. The H_2O can easily be removed by condensation and pure CO_2 is obtained. As a result, the requirement of CO_2 separation from flue gases, a major cost for CO_2 capture, is circumvented [3, 4].

To develop this promising technology for CO_2 capture at larger scale, further theoretical research work is needed. Both the development of adequate oxygen-carrier and an increased theoretical understanding of the behavior of this phenomenon in a continuous reactor system are necessary for the scale up of the process. CLC process, conventionally, is operated in fluidized bed reactor but large pressure drop, problems associated in solid gas separation make the packed bed reactor a better alternative, in particular, for extremely high pressure (20-25 bar) and temperature (1100-12000C) processes [5].

2 Materials And Methods

The CLC operated process in packed bed reactor (PBR) system is composed of two cycles, oxidation and reduction Fig-1, where the flue gas from reduction cycle contains CO2



and H2O and the flue gas from the oxidation cycle contains only N2 and some unreacted O_2. Thus, CO_2 and H_2O are inherently separated from the rest of the flue gases, and no major energy is burned up for this separation. Thus only one reactor is used where the solid particles are stationary with the alternate switching of the feed gas e.g. air over to syngas and vice versa. PBR is packed with catalyst as an active metal oxide and an inert support/binder. Hematite (Fe2O3) and TiO2 are the oxygen carrier material (catalyst) and the inert material, respectively [6, 7].

Theoretical model approach of the packed bed reactor (PBR) is based on the transient analysis of temperature of the reacting gas and concentration changes of the solid catalyst material and reacting gases along the length of the reactor. Theoretical model has been described in detail in previous studies [8, 9]. Model was run in Borland Delphi. Typical syngas composition is described in Table 1. Table 2 enlists the target variables simulation parameters for 1-D transient model simulation.

3 Results And Discussion

3.1oxidation Cycle

1-D transient model of CLC packed bed reactor is capable to simulate and predict the instantaneous temperature profile along the axis of the reactor which is useful in determining the maximum temperature change within the reactor and cycle time of the respective cycle. For example, consider the Figure 2 where simulation was run in oxidation mode. Bed temperature in options 1, 2 and 3 was kept constant at 132 0C, 450 0C and 750 0C, respectively. It can be observed that the maximum temperature reaches at the exit of the reactor at a certain time depending upon the weight fraction of active content of Fe2O3. Total cycle time during an oxidation cycle is distributed into three different time duration zones; $\Delta t1$ = time during which exit (reactor) air stream reaches the maximum temperature. $\Delta t2$ = time during which exit air stream remains at maximum temperature. $\Delta t3$ = time during which exit air stream temperature drops from maximum temperature to a stead state bed temperature. These time zones are of great importance while analyzing the different options in the contest of cycle efficiency. As high temperature exit stream will be used for power generation, the oxidation cycle with longer $\Delta t2$ is favored for the CLC process. Therefore, high temperature of the bed and the feed gas guarantees the shorter $\Delta t1$ and longer $\Delta t2$. On the other hand $\Delta t3$ is also of great significance as the gas stream during this time at that temperature can be flushed back into the reactor to keep the bed at relatively high temperature for the succeeding reduction cycle or the bed profile at this position of time and length of the reactor can be used for the succeeding cycle either the feed gas is introduced in the same direction or in opposite direction to that of the preceding cycle. The current study is based on the later phenomenon. It is, therefore, inferred from the Figure 2 that high temperature stream at the exit of the air reactor is achieved in less time and remains at that temperature for longer time. Furthermore, less quantity of Fe2O3 is needed if bed is heated initially to high temperature.

The only disadvantage is the heat penalty by keeping the bed and feed gas at high temperature.

Table 1: Syngas Composition

Species	Volume %
CO	60.5
H_2	21.9
CO_2	2.7
H_2O	0.3
N_2	14.6

Table 2: Base cases for 1-D transient reactor

Base case simulation	Feed temperature, T_{feed} (^{0}C)		Feed temperature, T_{feed} (^{0}C)		Flow direction of feed gas during consecutive cycle
Option number	Oxidation cycle	Reduction cycle	Oxidation cycle	Reduction cycle	
Op 1.1	450	132	132	Previous cycle profile	Reverse flow
Op 2.1	450	132	450	Previous cycle profile	Reverse flow
Op 2.2	450	132	450	Previous cycle profile	Reverse flow
Op 2.3	450	450	450	Previous cycle profile	Reverse flow
Op 2.4	450	450	450	Previous cycle profile	Reverse flow
Op 2.5	450	750	450	Previous cycle profile	Reverse flow

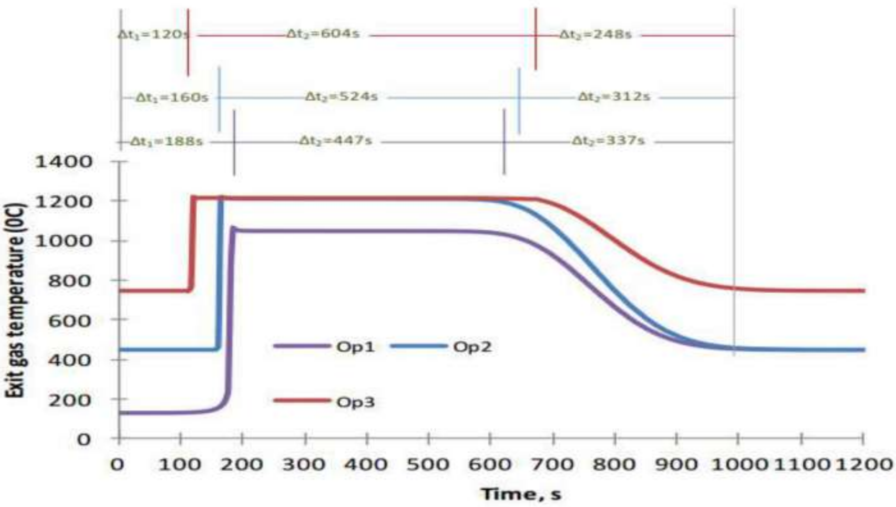


Figure 2: Transient temperature profile; Oxidation first cycle, Tbed = 1320C for Op1, 4500C for Op2, 7500C for Op3.

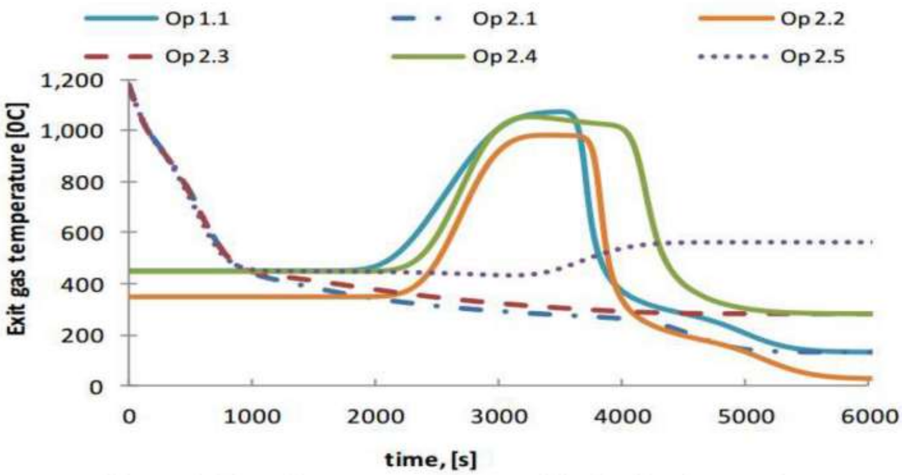


Figure 3: Transient temperature profile; Reduction cycle, Option 1 and 2; Solid line: feasible option; dashed lines: unfeasible option

3.2Reduction cycle

The study of theoretical behavior of the reduction cycle is equally important to investigate the temperature change, cycle time, fuel slip and the pressure drop for the design of reactor. It is found from the thermodynamic investigation that reduction reaction of syngas with hematite is exothermic as a dynamic change in temperature can be observed. Furthermore, temperature change is improved with the increase of hematite, initial feed (syngas) temperature and feed flow rate. Simulation is run for the fuel reactor under various operating and design parameters. The graphical representation of how temperature of the exit gas changes dynamically for the first reduction cycle is shown in Figures 3. It is noted that for each option, the bed profile of the preceding cycle of oxidation is utilized for the reduction cycle. It is observed that for those reduction options, exit gas stream remains at high temperature for certain time duration if reduction cycle is operated counter currently. In fact, by reverse flow, the feed gas takes in the heat of bed throughout the length of the reactor before the bed cools back to feed gas inlet temperature. Like the oxidation cycle, this high temperature gas stream can also be used for to run the steam turbine for power generation. The dashed lines in Figure 3 denote the unfeasible options which provide insufficient heat for the syngas to be reduced with hematite.

4 Conclusions And Outlook

A numerical 1-D transient model of dynamically operated packed bed reactor was analyzed for the reactor performance at high operating and design parameters. The temperature profile for the different options was investigated to meet the target objectives. It was found that the amount of Fe_2O_3 (hematite) distributed in the bed is used to control the temperature of exit gas stream, in particularly from air reactor. Thus a correct amount of hematite should be selected for the first cycle at the start of the process. Cycle time is important since shorter cycle time might give less bed breading and less critical reduction of the material but also much better conversion of the syngas to steam and CO_2. For the same direction flow the feed air during all the oxidation cycle should be heated to 750 0C thus the bed remains at 750 0C at the end of oxidation cycle and start of the next reduction cycle.

5 References

[1] D. Aoron; C. Tsouris. Separation of CO2 from flue gas: A review. Sep. Sci. Technol. 2005, 40. 321.

[2] B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. meyer. IPCC, 2007: Climate change 2007: Mitigation.

Contribution of working group III to the fourth assessment report of the intergovernmental panel on climate change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

[3] M. Ishida, H. Jin. A novel chemical-looping combustor without NOx formation. Industrial and Engineering Chemistry Research, 1996, 35(7): 2469-2472.

[4] F. Mattisson, F. Garcia-Labiano, F. B. Kronberger, A. Lyngfelt, J. Adenez, H.

Hofbauer. Chemical-looping combustion using syngas as fuel. International Journal of Greenhouse Gas Control, 2007, 1(2): 158-169.

[[7] A. Abad, J. Adanez, A. Cuadrat, F. GarciaLabiano, P. Gayan, L.F. de Diego. Kinetics of redox reactions of ilmenite for chemical-looping combustion. Chem. Eng. Sci. 2011, 66:689-702.

[8] J. Adánez, A. Cuadrat, A. Abad, P. Gayán, L.F. de Diego, F. García-Labiano. Ilmenite activation during consectutive redox cycles in Chemical-Looping Combustion. Energy & Fuel, 2010, 24: 1402–1413.

[9] M. Younas, I. K. Swati, I. Ali, N. Ullah, M.I. Ahmad, Performance study of a lab scale packed bed Chemical Looping Combustion reactor:

Part b) Oxidation cycle. J. of the Pakistan Institute of Chemical Engineers, Lahore. 40 (1) 2012: 109- 114.

[10] M. Younas, I. K. Swati, I. Ali, N. Ullah, M.I. Ahmad, Performance study of a lab scale packed bed Chemical Looping Combustion reactor:
Part a) Reduction cycle. J. of the Pakistan Institute of Chemical Engineers, Lahore 40 (1) 2012: 114-119.
5] M.M. Hossain, H.I. de Lasa. Chemicallooping combustion (CLC) for inherent CO2 separations:
A review. Chemical Engineering Science. 2008, 63, 4433-4451.

[6] A. Lyngfelt, B. Leckner, T.A. Mattisson. Fluidized-bed combustion process with inherent CO2 separation;

application of chemical-looping combustion. Chem. Eng. Sci. 2001, 56:3101-3110.

Improving Site Safety through Building Information Modeling

Engr. Rizwan U. Farooqui
rizulhak@neduet.edu.pk

Engr. Raja Shahmir Nizam
aj_mir@hotmail.com

Engr. Syed Muhammad Ali
Syed.muhammadali@aaaprojects.com

Abstract
Safety in the Construction and engineering service sector is one of the most neglected project success parameter within Pakistan. There is no or little acceptance of safety practices in construction industry because of lack of awareness in this facet. This awareness can be imparted through a communication mechanism that is comprehensive and relatable. Issuing site specific Videos regarding safety procedures is the best way to bridge the gap. This paper discusses development of Building Information Model (BIM) of case project and applying different safety layers; namely "Fall Protection Plan" and "Protection from falling Objects" are added to the 3D model. Case project selected is the hotel tower of the two towers of Bahria Town Icon (a multi-use commercial building project). Finally time lapsed videos of the construction phase are made showing different safety procedures to be followed. This will allow implementation of safety regulations and enhance the overall safety management process. It will also deliver a concept for reducing accidents and analyzing possible hazardous circumstances that might occur at a construction site.

Keywords
BIM, Construction Safety, Fall Protection, Falling Objects

Introduction.
In Pakistan many construction firms do not provide training programs for the staff and workers; therefore, new workers are unaware of the potential hazardous areas on site, and no safety meetings are held. Employees are required to learn from their own mistakes or experience. In addition, lack of medical facilities and substandard sanitation tend to exist on remote projects (Farooqui et al., 2008). Despite the recent technological advances, the fatality and injury rates in the construction industry have still not considerably declined. It is partially because designers do not have adequate construction safety knowledge, which results in many inherent safety hazard loopholes in the project design. Similarly, it is very hard for contractors to identify all possible hazards in the project planning and preconstruction phases. Each construction site has its specific hazards and these differ from one location to another. New employees usually come on board without prior knowledge about the possible hazards they may have to face. Typically contractors use CAD based construction drawings to plan for safety. While these CAD-based models provide a topological description of buildings, they are not suitable for properly identifying construction hazards at jobsites. To improve the current situation, BIM (Building Information Model) technologies can be used as a new safety planning tool.

(Azhar et al., 2012) BIM has a great impact on construction safety. BIM can provide a complete 3D and 4D visualization to enhance the construction safety. Once a 3-D model is developed, it can be used for many purposes, including worker safety training and education, safety planning and employee involvement. Safety professionals do not need to be experts in model creation or its technical aspects; they simply need a basic understanding of BIM, which is essentially a 3-D computer- aided design drawing. (Rajendran et al, 2011). BIM technology has the potential to be used in safety planning procedures particularly those related to tasks on construction sites (John et al 2011). BIM technologies are generally seen as means to facilitate communication in relation to safety aspects (Eastman et al, 2008; Suermann&Issa, 2007; Heesom&Mahdjoubi, 2002; Khanzode&Staub-French, 2006). BIM technology can result in improved occupational safety by connecting the safety issues more closely to the construction planning, providing more illustrative site layout and safety plans, providing methods for managing and visualizing up-to date plans and site status information, as well as by supporting safety communication in various situations, such as informing site staff about coming safety arrangements or warning about risks (Sulankivi et al. 2010).

BIM-enabled virtual safety controls can be used to detect and alert designers and contractors to potential project hazards. Buildings can be simulated at various stages of the construction process to allow engineers, architects and contractors to identify potential safety and health hazards at an early stage of the project. If the hazards are identified during the design phase, elimination and Substitution of hazards may be inexpensive and simple to implement. BIM can be an effective tool to maximize safety and convenience while minimizing costs (John et al., 2011; Puerto et al., 2009).

Fall Protection Plan

The purpose of the fall protection plan is to ensure all construction areas are free from uncontrolled fall hazards, all employees are properly trained in fall prevention and fall prevention systems are inspected and monitored to ensure effectiveness. The fall protection plan for leading edges is prepared according to OSHA"s fall protection standards. After modeling the fall protection railing components, the railings are placed on the structural BIM model. While performing this process, the researchers were able to identify multiple fall hazards through the 3D view that were not easily identifiable in the 2D plan view.

Protection from falling Objects- Safety Net Systems

When workers are working at different levels there is a safety hazard of falling objects (tools or material from a higher level may fall on a worker at lower levels). Safety nets protect workers from being exposed to such conditions. As per OSHA standards safety nets must be installed as close as practicable under the walking/working surface on which employees are working and never more than 30 feet (9.1 meters) below such levels. Defective nets shall not be used. Safety nets shall be inspected at least once a week for wear, damage, and other deterioration. The maximum size of each safety net mesh opening shall not exceed 36 square inches (230 square centimeters) nor be longer than 6 inches (15 centimeters) on any side, and the openings, measured center-to- center, of mesh ropes or webbing, shall not exceed 6 inches (15 centimeters). All mesh crossings shall be secured to prevent enlargement of the mesh opening. Each safety net or section shall have a border rope for webbing with a minimum breaking strength of 5,000 pounds (22.2 K Newton). Connections between safety net panels shall be as strong as integral net components and be spaced no more than 6 inches (15 centimeters) apart.

Software Used

Revit 2014

Revit software is specifically built for Building Information Modeling (BIM), empowering design and construction professionals to bring ideas from concept to construction with a coordinated and consistent model-based approach. Autodesk Revit is a single application that includes features for architectural design, MEP and structural engineering, and construction. It allows users to design a building and its components in 3D, annotate the model with 2D drafting elements and access building information from the building models database. Revit is 4D BIM capable with tools to plan and track various stages in the building's lifecycle, from concept to construction and later demolition.

Navisworks Manage 2014

Navisworks software helps architecture, engineering, and construction professionals holistically review integrated models and data with stakeholders to gain better control over project outcomes. Integration, analysis, and communication tools help teams coordinate disciplines, resolve conflicts, and plan projects before construction or renovation begins. It provides facility to import models from wide range of file formats, to perform different tasks such as clash detection, simulated safety plan and to generate 3D/4D visualizations for better communication in different formats as desired.

Adobe After Effects CS5

Adobe After Effects is visual based software which helps in creating motion graphics, animation, and alteration in 2D and as well as 3D space. It is layer oriented software which means each video clip, audio clip and still image has its own layer and occupies a different track although they can run at a same time simultaneously. Al l the editing and alterations can be performed separately and combined to form a single video format.

Sketch Up Pro

Sketch Up is a 3D modeling program under Google ownership which helps in creating a wide range of applications such as architectural, civil, mechanical and even video game design. This software also includes a wide range of operation related to navigation, mapping, surveying and even Geographic Information System (GIS). 3D modeling is done through very simplified steps such as drawing basic polygons and making their offsets. These shapes are given a finished look by rotating, moving, pushing and pulling in the way a user wants. It all starts with the orientation on the 3 basic axes. Whatever is drawn, Sketch Up anticipates the values and angles, which are almost exactly what user want to do.

SCOPE

The scope of this study is limited to the development of fall protection plan and protection from falling objects plans for the hotel tower of Bahria Town Icon (BTI).

Objectives

The objective of this study is to propose a BIM based Safety Management Plan comprising of videos for fall protection and protection from falling objects procedures for Case Project.

Methodology

Forachieving the objective of proposing a BIM based Safety Management Plan for case project, following steps are followed:

1. Understanding of the BIM tools (to be used in the Construction Safety Plan) were developed.
2. 2D drawings were collected for the case project and meetings were conducted with Project Manager to understand the safety needs.
3. A BIM model was then created for that particular site with the help of the available data.
4. Safety layers were added to the developed BIM model. Following are the 2 dimensions on which a safety plan through a BIM model was created:

? Fall protection plan
? Protection from falling objects

Case Study

Data Collection

In order to generate the 3D models of the selected floor, 2D drawings are provided by the AAA Partnership Private Limited including the following details:

? Plans
? Profiles (Elevations)
? Sections

Case Project Introduction

Bahria Town Icon is a skyscraper under construction in Karachi, Pakistan which is the tallest building project in all over Pakistan. The skyscraper after its completion would be the tallest building in Pakistan. The project was initiated in 2008 after the approval of KBCA and the excavation. Creation of haul routes and foundation works has been undertaken. It is expected to be completed by the end of 2015. The Bahria Town Icon Tower is a multi-use commercial building project. It will be 853 ft. tall and is being constructed on a 1.45 hectares (3.58 acres) area plot located opposite to the Bin Qasim Park in Clifton, Karachi. A historical landmark in the making, Bahria Icon will stand tall as a vanguard of futuristic hi-rise developments in the country. Fusing visionary aesthetics with functionality, it will be an icon indeed. Offering beautiful panoramic views, the iconic structure with its revolutionary design symbolizes modernity and boasts of exclusive engineering expertise.

Project Stakeholders

The stakeholders of this project are tabulated in Table 1.

Client	Galaxy Construction (Pvt.) Ltd, Pakistan
Project Manager	AAA Partnership (Pvt.) Ltd, Pakistan
Lead Structural Designer	WSP Cantor Seinuk, Dubai, U.A.E
Structural Designer (Local)	ESS-I-AAR, Pakistan
M.E.P (Mechanical, Electrical & Plumbing) S. Mehboob & Company, Pakistan (SMC)	
Architects	Arshad Shahid Abdulla (Pvt.) Ltd, Pakistan (ASA)

Table1: List of Stakeholders

Model Generation

The drawings collected from the Bahria town Icon site included both Office tower and hotel tower drawings. The model for the Hotel tower was developed as per the directions of the site representative. There were three types of floors in the building structure that were designed which are enumerated as follows:

1. **7 floors Basement up to the ground level**
2. **1st floor till 14th floor**
3. **15th floor till 40th floor**

The complete 3D model of the Bahria town Icon"s hotel tower developed on Revit is shown in

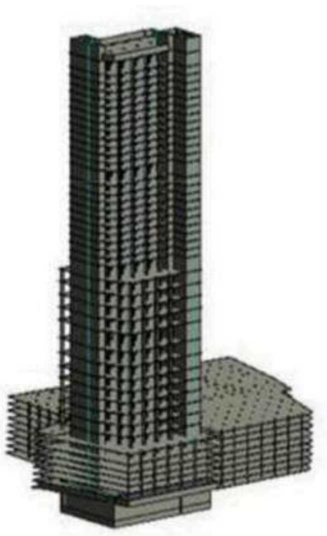


figure 1.

Figure 1: 3d Model

Fall protection plan

Guardrails as per safety standards was created using Autodesk Revit. These are placed on the hazardous locations on site using safety considerations. 3D model, schedule and created objects were then imported to Navisworks for simulation. Figure 2 shows snapshot of views from the video created in Navisworks for fall protection plan.

Figure 2: Railing installed on Roof

Protection from falling objects

Safety net as per safety standards was created using Autodesk Revit. These were placed on the hazardous locations on site using safety considerations. 3D model, schedule and safety net were then imported to Navisworks for simulation. Figure 3 shows the safety nets installed in the building.

Figure 3: Safety Net Installed In Building Conclusion 6th ICEC 2013

This paper presents a BIM model of a commercial building, safety layers were imposed on the model. Videos were developed for training workers for implementing safety during the construction phase. This method is a combination of creation of 3D models, visualization and textual representation in safety aspect which makes it 4D. The project also shows that 4D models created with the method give practitioners awareness in problems and hazards that might arise during the construction of Hotel Tower (BTI) and enables practitioners to choose an appropriate way of visualizing for several processes and measures. The visual representation of the construction sequence offered by the 4D models will help the site staff to understand the complexities and hazards much easier and quicker.

References

Azhar, S., Khalfan, M., & Maqsood, T. (2012). Building information modelling (BIM): now and beyond. Australasian Journal of Construction Economics and Building, 12(4), 15-28. Eastman, C., Teicholz, P., Sacks, R., & Liston, K.(2011).

BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors. Wiley.com. Farooqui, R.U. Arif F& Rafeeqi, S.F.A.(2008).

Safety performance in construction industry of Pakistan. Construction in Developing Countries, 74 Heesom, D. & Mahdjoubi, L. (2002).

A dynamic 4D simulation system for construction space planning. International conference on Decision making in civil and urban engineering (DMinUCE), London, 6–8 November 2002.

John, G.A. & Ganah, A.(2011). Integrating BIM and Planning Software for Health and Safety Site Induction. Puerto, C. L. & Clevenger, C. M. (2009).

Enhancing Safety throughout Construction using BIM/VDC Rajendran, S. Clarke, B. (2011).Building Information modeling: safety benefits and opportunities, Professional safety Staub-French, S & Khanzode, A. (2007).

3D and 4D modeling for design and construction coordination: issues and lessons learned. ITcon, 12, 381-407.

Sulankivi, K., Kähkönen, K., Mäkelä, T. Kiviniemi, M. (2010),

4D-BIM for Construction Safety Planning Suermann, P.C. and Issa, R.R.A. (2007).

Evaluating the impact of building information Modeling (BIM) on construction, Proceedings of the 7th International Conference on Construction Applications of Virtual Reality The Pennsylvania State University October 22-23, USA. 10 pp.

Analysis and Design of Common Effluent Treatment Plant for Reuse

Engr. Syed Imran Ahmed

Engr. Muhammad Ahsan Siddique

Engr. Syeda Fatima Bushra, Engr. Ahsan Ali Khan, Engr. Sadia Ajmal, Engr. Nazeer Malik, Engr. Muhammad Shoaib, Engr. Mavra Rizvi
Students of Bachelor of Civil Engineering, NED University of Engineering & Technology, Karachi, Pakistan.

Abstract
Industries of Karachi are using huge amount of fresh water causing water shortage for residents. Moreover effluents from these industries are directly dumped without any pretreatment which causes environmental pollution and disturbs marine life. The aim of this study was to identify the effective method for effluent treatment to save water and water bodies. The study covers industrial area at Shershah. Samples were taken from four different outlets which have the discharge point contributing to Liyari River. Parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Potential Hydrogen (pH), Total Suspended Solid (TSS), and Total Dissolved Solid (TDS) were tested in Pakistan Council of Research in Water Resources laboratories, whereas testing of metals was done in Pakistan Space and Upper Atmosphere Research Commission (SUPARCO). Test results show that the samples are far beyond the permissible limit of National Effluent Quality Standards (NEQS) and WHO Standards except the metal contents which are under permissible limits. It becomes necessary to treat effluent from multiple industries before discharge or for further reuse. For this purpose common effluent treatment plant has been selected and the activated sludge is used as the main biological treatment process. A common effluent treatment plant is designed which can handle a flow of 6 MGD and it has the ability to reduce TSS up to 80.9%, BOD 80.8%, and COD 94.5%. Variant pH values and heavy metals are within permissible limit. Heavy metals gets settle down and can be removed along with waste sludge. If any industry desires more improved wastewater quality they can go for more advance treatment.

Introduction
Surface water pollution has enlisted as one of the most serious problems in developing countries (Suthar et al., 2010). Effluents from many industries are discharged into rivers, which cause water pollution (Qureshi, 2002). Most of the rivers in the developing world are the end point of effluents discharged from industries (Phiri et al, 2005). Most of the industries are therefore located near water sources (Azumi and Bichi, 2010). According to a water pollution report, Karachi discharges around 446 MGD of wastewater untreated into storm-drains, open Nalahs or in Rivers which ultimately falls into sea. The Lyari and Malir Rivers, which run through Karachi, Pakistan"s largest industrial city, are open drains used to discharge untreated industrial effluents (Helmer et al., 2011). Reusing these effluents can have a significant impact on reducing or completely removing the impact of these effluents from receiving environments (Toze, 2006).

According to Visvanathan and Asano (2007) Interest in reuse is now growing in other parts of the world but it has only been in the last quarter of this century that wastewater reuse technologies have been adopted in Asia. Therefore there is a need of study used to treat industrial effluent before it gets dumped.

Common Effluent Treatment Plant (Cetp)

It is difficult for each industrial unit to provide and operate individual wastewater treatment plant because of the scale of operations or lack of space or technical manpower (Vasudevan et al., 2012). Therefore in many countries concept of Common Effluent Treatment Plant CEPT has widely been used. The Common Effluent Treatment Plants (CETPs) are considered a viable treatment solution for collective treatment of effluents, particularly from small and medium scale industries. CETPs could potentially help in achieving treatment of combined wastewater from various industries at lower unit costs and also help facilitate better compliance and monitoring with standards (Partnership, 2012). Common effluent treatment plant (CETP) is based on activated sludge treatment process. This process is carried out in aeration lagoons at CETP where a flocculent mixture of an aerobic heterogeneous population of microorganisms and wastewater are aerated resulting in the consumption of soluble organic material and entrapment of suspended particulate matter by from wastewater (Pathe et al., 2005; Gernaey et al., 2004). The wastewater treatment processes carried out in aeration lagoons at common effluent treatment plant (CETP) are most widely accepted methods for the degradation and detoxification of domestic as well as industrial wastewaters (Moharikar et al.

2005 Kapley et al., 2007; Moura et al., 2009). Degradation of industrial wastewater in these systems involves a complex suite of interactions between resident microbial species (Kapley et al., 2007; Munz et al., 2008). However, the microbial diversity growing in aeration lagoons of CETP is largely depend on the nature of pollutants and geographical conditions and changes in microbial diversity can compromise the entire wastewater treatment process (Chandra et al., 2011).

In CETP wastewater effluents from various industries are collected through pipelines and mixed in the Equalization tank of the plant before it enters into the effluent treatment plant that is specifically designed and operated for the treatment of wastewater containing chemicals.

Then in the Chemical dosing tank FeSO4 and other coagulants like alum, lime, polyelectrolytes are added. pH neutralization is also done here. In Primary clarifloculator, settling or sedimentation removes suspended solids and colloidal matter. The supernatant liquid is pumped to the activated sludge basin while settled sludge is sent to the sludge drying beds. This sludge is referred to as chemical sludge. The supernatant coming from Primary clarifier is given biological treatment in activated sludge basin. In Secondary clarifier the sludge is separated and sent to drying beds. This sludge is referred to as biological sludge. The clear supernatant is discharged as effluent water into river (Rao et al., 2005, Kapley et al., 2007, Mathur et al., 2007, Chandra et al., 011)

Pollution prevention concepts must be applied not just to those who send wastes to the plant but to the CETP itself and to the discharges made by the CETP, in the form of effluent waters, sludge and air pollution. In other words, pollution prevention must be integrated with the very design and economics of CETP (Mathur et al., 2007)

Objective

The objective of the study was to identify economical treatment method, analysis, and design of a common effluent treatment plant (CETP) for the reuse of effluent coming from Shershah industrial area, Karachi.

Methodology

Research of this study consisted of previous research work and review of literature regarding CETP. Survey the respected area and identify the various industries situated in and around the Shershah, identified industries are enlisted in Table 1. Data and wastewater samples were acquired from four different locations. Three samples were collected from small outlets whereas the fourth one was from main and common dumping outlet i.e. under Mera Nakah Bridge, Lyari River. The collected samples were passed through different tests in Pakistan Council of Research in Water Resources (PCRWR), Karachi, and Pakistan Space and Upper Atmosphere Research Commission (SUPARCO), Karachi, to find out concentrations of different pollutants present in the wastewater. The results were compared with the permissible limit as set by WHO and NEQS. The average results of these tests are mentioned in Table 2. Based on literature review, the most suitable and economical method and design for CETP was slected. Cost estimation is also carried out by using different equation and charts. The methodology flowchart is shown in Figure 1.

Physical characteristics of the effluent

Observation of temperature of effluents is useful in indicating the solubility of oxygen which affects oxygen transfer capacity of aeration equipment and rate of biological activity. Color and odor indicates the colloidal portion and need for specific treatments chemical/membrane units. Total solids include. both the suspended solids and the dissolved solids which are obtained by separating the solid and liquid phase by evaporation.

Typically, suspended solids carry a significant portion of organic material, thus significantly contributing to the organic load of the wastewater. Hence, effective solids removal can significantly contribute to wastewater treatment.

Chemical characteristics of effluents

The biological treatment units at CETP are sensitive to pH of the effluent. In addition, acidic effluents cause corrosion related problems. Carbonaceous constituents are measured by BOD, COD or TOC analysis. While the BOD has been the common parameter to characterize carbonaceous material in wastewater, COD is becoming more common in most current comprehensive computer simulation design models.

The BOD test gives a measure of oxygen utilized by bacteria during the oxidation of organic material contained in a wastewater sample. The test is based on the premise that all the biodegradable organic material contained in the wastewater sample will be oxidized to $CO2$ and $H2O$, using molecular oxygen as the electron acceptor. Hence, it is a direct measure of oxygen requirements and an indirect measure of biodegradable organic matter.

The COD test is based on the principle that most organic compounds are oxidized to $CO2$ and $H2O$ by strong oxidizing agents under acidic conditions. COD will always be equal or higher than BOD, as the test is under strong oxidizing agent, which oxidizes to greater extent, including inorganics. The total organic carbon analyzer allows a total soluble carbon analysis to be made directly on an aqueous sample. In many cases, TOC can be correlated with COD and occasionally with BOD values.

As the time, a common effluent treatment plants requires for carbon analysis is generally short, such co- relations are extremely helpful for efficient control of day-to-day operations of treatment plant. Some heavy metals and compounds such as chromium, copper, etc., will determine the precipitation of biological treatment.

Design Of Cetp

In Common Effluent Treatment Plant, one universal treatment system is used to treat the effluents discharged from different industries. This plant eliminates the duplicity of treatment system among different industries in an industrial area and thus results in the reduction of total capital cost required to install separate treatment plant for each industry in an industrial estate. The CETP is design for a flow rate of 6 MGD The different levels of treatment and there steps are summarized in Figure 2.

Preliminary Treatment.

The preliminary treatment includes facilities of screening, grit chamber and Flow Equalization Basin.

We are using coarse reciprocating rake screen of size through Horizontal flow grit chamber with a dimension of 19.5m x 1.9m x 1.25 m and the detention time is 60 sec. after this it will going through channel of size 25m x2m x1.5 m.

Using in line flow equalization tank; in which all the flow passes through equalization basin. While side-line units, where only that amount of flow above the desired flow rate (usually design average flow) is diverted through the equalization basin(s). Providing two flow equalization tank with Diameter = 33 m and Side Water Depth = 4 m and its Hydraulic Retention Time will be 3 hours for each tank.

Primary Treatment

The preliminary treatment includes primary sedimentation tank. Water depth value is assume to be 4m using two circular tank with a diameter of each tank of 19m. After 2hr retention time 32.25% of BOD, 56.33% of TSS and 51.6% of COD is removed.

Secondary Treatment

Secondary Treatment comprises of Activated Sludge process system which further remove the impurities left after primary treatment. Three 27m x 27m x 4m aeration tanks is used to treat approx. 2 MGD of wastewater (each tank) having a F/M ratio is 0.25 after 9 hr retention time it is moving to secondary sedimentation tank where solid is separate from liquid i.e. sludge is separate from treated effluent with a 79m3 / day of volumetric flow of the waste sludge and 0.64MGD of sludge is taken back to aeration tank so that it will again contact with new effluent. We use coarse bubble type diffuser which has 7% oxygen transfer efficiency; Volume of air to be supplied is 21828 m3air /day. At this stage 71.64% BOD, 90.5% COD and 56.33% of TSS is removed. Metals presents in the wastewater are within limit, and there is no need to treat them as they settle down and remove with sludge. The summarized technical details of the treatment unit and the concentration of parameter removal are listed in Table 3 and 4, respectively.

The complete design of CETP is summarized through flow chart in Figure 3.

Cost Estimation

The Economic and Social Commission for Western Asia (2003) states that cost is an integral factor in any design. We want the project to be efficient but at the same time economical. Therefore an economic analysis is always in order. The selection and design of waste-water treatment facilities is greatly dependent on the costs associated with treatment processes, including capital investment, operation and maintenance, land requirements, sludge handling and disposal and monitoring costs.

Zahid (2007) says that wastewater costs can be basically divided into two categories: capital costs and operation and maintenance (O&M) costs. Capital costs are incurred during plant construction while O & M costs are those necessary to operate and provide upkeep for the plant following construction. Table 5 gives summary of cost.

Conclusion And Recommendation

The increase in the living standards through uncontrolled industrial development has resulted in depletion and pollution of water resources. These reasons have forced the industries to treat the effluent before final disposal or to promote the combined effluent treatment coming from various, industries. Reusing of wastewater is an attractive economic alternative and helps in conserving the basic need of life. It will also reduce the amount of waste water that is being discharged into the water bodies. The conclusions drawn from the study are:

1. This study indicates that the untreated effluent which is directly discharging into the Lyari river has wastewater characteristic values, i.e. BOD, COD, TDS, TSS etc. much far beyond the set standards.

2. DesignCETP can efficiently remove these unwanted parameters and will take it to the limit such as TSS up to 81%, BOD 81% and COD 95%.

3. The CETP is being designed for 6 MGD of wastewater that can treat the wastewater up to the permissible limit as set by the NEQS, Pakistan.

4. All pH, DO, and heavy metals are within NEQS limit and they settled down and can remove with sludge during the treatment.

Since design plant follows NEQS, if any industry requires more quality effluent for recycling or reuse purpose, the design can further go for tertiary treatment process and treat the wastewater up to their required quality. Karachi Water & Sewerage board and industrial owner can also directly get benefited from this project. It will replace the fresh water supply to the industries with the treated water which causes a huge reduction in amount that the industries paid to the KW&SB for fresh water. Wastewater treatment and its reuse save the water bodies, and marine life from the toxic discharge and thus the environment. The reduction in fresh water supply to the industries will increase the amount of water supply to society so consequently local people get benefited.

References

Azumi and Bichi M.H., "Industrial Pollution and Implication on Source of Water Supply in Kano, Nigeria," International Journal of Engineering and Technology, Vol.10, 2010, pp. 1.

Chandra, R., Bharagava, R.N., Kapley, A., and Purohit, H.J., "Bacterial diversity, organic pollutants and their metabolites in two aeration lagoons of common effluent treatment plant (CETP) during the degradation and detoxification of tannery wastewater," Bio resource Technology, Vol. 102, 2011, pp. 2333-2341.

Gernaey, K.V., Loosdrecht, M., Henze, M., Lind and Jorgensen S.B., "Activated sludge wastewater treatment plant modeling and simulation," State of the art, Environ. Model Software, Vol. 19, 2004, pp. 763-783.

Helmer, R., and Hespanhol, I., "Environmental Health Hazards," Encyclopedia of Occupational Health and Safety, 2011.

Kapley, A., Baere, T.D. and Purohit, H.J., "Eubacterial diversity of activated biomass from a common effluent treatment plant," Research in Microbiology, Vol. 158, 2007, pp. 494-500

Mathur, N., P. Bhatnagar, K., Mohan, P., Bakre, Nagar, P. and Bijarnia, M., "Mutagenicity evaluation of industrial sludge from common effluent treatment plant," Chemosphere, Vol. 67, 2007, pp. 1229- 1235.

Moharikar, A., Kumar, R. and Purohit, H.J., "Microbial population dynamics at effluent treatment plants," J. Environ. Monitor, Vol. 7, 2005, pp. 552-558.

Moura, A., Tacao, I. Henriques, J. Ferreira, P. and Correia, A., "Characterization of bacterial diversity in two aeration lagoons of a wastewater treatment plant using PCR–DGGE analysis," Microbiological Research, Vol. 164, NO. 5, 2009, pp. 560-569.

Munz, G., Gualtiero, L. Salvadori, B., Claudia and Claudia, L., "Process efficiency and microbial monitoring in MBR (membrane bioreactor) and CASP (conventional activated sludge process) treatment of tannery wastewater," Bio resource Technology, Vol. 99, 2008, pp. 8559-8564. Partnership, I.G.E., "Common effluent treatment plant, India," 2012.

Pathe, P.P., Biswas, A.K., Rao, N. and Kaul, S.N., "Physico-chemical treatment of wastewater from clusters of small-scale textile units," Environ. Technology, Vol. 26, 2005, pp. 313-327.

Phiri, O., Mumba, P., Moyo, B.H.Z. and Kadewa, W., "Assessment of the Impact of Industrial Effluents on Water Quality of Receiving Rivers in Urban Areas of Malawi," International Journal of Environmental Science & Technology, Vol. 2, No.3, 2005, pp. 237–244.

Qureshi, I.H., "Assessment of Water-Quality." 2002.

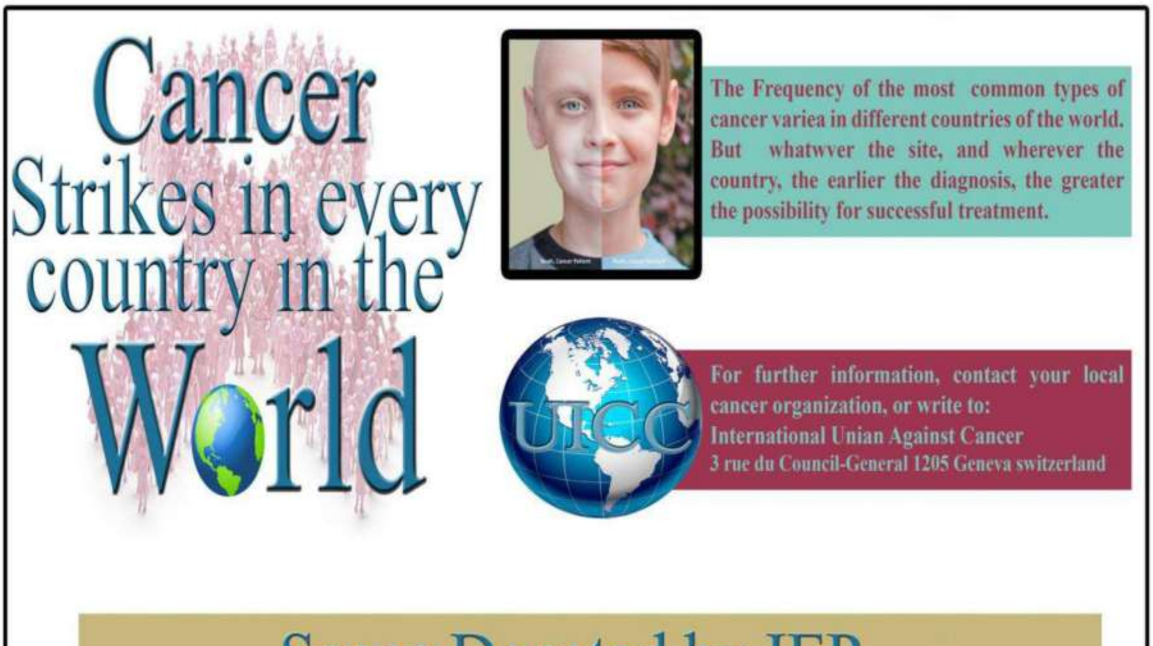
Rao, N. C., Mohan, S.V., Muralikrishna, P. and Sarma, P.N., "Treatment of composite chemical wastewater by aerobic GAC-biofilm sequencing batch reactor (SBGR)," Hazard Mater, Vol.124, 2005, pp. 59-67.

Suthar, Sharma, J., Chabukdhara, M. and Nema, A. K., "Water Quality Assessment of River Hindon at Ghaziabad, India: Impact of Industrial and Urban Wastewater," Environmental Monitoring and Assessment, Vol. 165, 2010, pp. 103-112.

Toze, S., "Reuse of Water-Benefits and Risks," Agricultural Water Management, Vol. 80, August 2005 pp. 147-159.

Vasudevan, N., J. Aaron, P.S. and Greeshma, O., "Performance evaluation of a common effluent treatment plant for tannery industries," Journal of Eco biotechnology, Vol. 4, No. 1, 2012, pp. 25-28.

Visvanathan, C., and Asano, T., "The Potential for Industrial Wastewater Reuse." Department of Civil and Environmental Engineering, University of California at Davis, California, 2007, 3-6



Effect of Heat Treatment on the Corrosion Rate of AISI 1045 Steel

When Subjected to Various Work Environments

Engr. M.Rizwan
materialist.riz@gmail.com

Engr. M Ali

Engr. M Samiuddin

Abstract

Carbon steels are by far the most economical and one of the most used materials throughout the world. In this work the usability of AISI 1045 steel has been studied in various practical environments. The corrosion behavior of AISI 1045 steel has been observed having been heat treated and subjected to various environments. Several samples in Annealed, Normalized and quenched state were subjected to LPR (Linear Polarization Resistance) testing to determine Corrosion rate of each sample in different environments by Potentiostat using Dr.Bob's Cell. LPR test results revealed the corrosion behavior of each sample in particular environments. Results of this experiment can be very helpful to decide that, in which environments AISI 1045 steel can be used and which heat treated conditions suits that particular environment.

Keywords: AISI 1045, LPR, Potentiostat.

1 Introduction

The corrosion of metals is the primary concern to the engineers in desalination, petrochemical and power plants. Like other natural disasters such as floods or severe earthquakes, corrosion can be very disastrous for everything from vehicles, home appliances, and water and wastewater systems to pipelines, bridges, and public buildings.

The dependence of Microstructure on Corrosion behavior of Carbon steels is widely recognized. Many contradictory results are present in literature due to the fact that the involved mechanisms are quite complex [1].

AISI 1045 is a medium carbon steel which is quite common material for general Engineering applications requiring strength and wear resistance, Such as; Gears, Ratchets, Bolts and Axles Corrosion behavior of metals depends largely on the phases present in the alloy. Heat treatment may be utilized to produce several phases and their combinations in a steel sample. In this work the corrosion behavior of AISI 1045 steel has been studied for annealed, normalized and hardened samples.

The corrosion behavior of any metal depends on the environment conditions to which it is exposed [2].

One of the most corrosive environments for Carbon steels in practical applications are sea water, hydrochloric acid, sulphuric acid and nitric acids.
Electrochemical techniques are the most widely used method to determine corrosion behavior of materials in laboratory. Linear Polarization Resistance (LPR) is the most common technique for Corrosion rate determination [3].

2 Experimental Work

Material Selection 24 cylindrical samples (L=60 mm & Dia=7 mm) of AISI 1045 steel were prepared by machining. The chemical composition of the samples is, as shown in Table 1:

Table 1. Chemical compositions of AISI 1045 type steel (WT %), Iron as balance

Elements	C	S	Mn	Al	Si	Cu	Cr
Composition (%)	0.470	0.02	0.65	2.8	1.5	0.15	0.2

2.1Heat Treatment

6 samples were then allocated for each Heat treatment, i.e Annealing, Normalizing, Water quenching and Oil quenching. After austenitizing and subsequent holding, all the samples were cooled according to the desired microstructure. Each sample was then ground to remove surface oxide layers.

2.2Corrosion testing

Linear Polarization resistance test was used to check Corrosion rate on calibrated Gamry Potentiostat (Refrence 600) with Dr. Bob's cell. Samples were used as working electrode while Ag/AgCl Standard Calomel Electrode (SCE) was used as refrence electrode. Pt electrode acted as counter electrode. Following chemicals were used as electrolyte: Seawater 1M Boric acid 33% HCl 65% HNO3 LPR curves were obtained by scanning the samples in appropriate ranges. Samples tested in sea water were scanned from -1.2 mv to 0mv, while those tested in Boric acid were scanned from -1.2mv to 2mv. Samples in HCl and H2SO4 were scanned between -1.2 mv to 0 mv while samples in HNO3 were scanned between 0mv to 2mv. Corrosion rate in mpy (mills per year) is calculated directly by the Gamry software.

2.3Microstructural analysis

All samples were than ground and polished to mirror finish. These samples were than quenched in Nital and then analysed on Metallurgical microscope to develop the relation between phases and corrosion behavior.

3 Results And Discussion

3.1linear Polarization Resistance Test Results In Seawater

Annealed, normalized, water quenched and oil quenched samples were tested in sea water. LPR curve shows that water quenched sample shows minimum corrosion current and corrosion rate (i.e20.5mpy) among all sample tested in sea water Fig-1.

The corrosion rate obtained for oil quenched sample is 25.74 mpy. The corrosion rate obtained for water quenched sample is 20.51 mpy. The corrosion rate obtained for normalized sample is 28.96 mpy. The corrosion rate obtained for annealed sample is 27.67 mpy. Water quenched sample shows the least corrosion in sea water because it has single phase on surface (i.e Martensite can also be observed in Figure 7). In other heat treated samples, multiple phases are present (i.e Pearlite: which is a combination of Ferrite and Cementite).

3.2Linear Polarization Resistance test results in Boric acid

Boric acid which is a weak acid, corrodes steel in the similar manner as sea water does. Corrosion rate for Martensite (Water quenched) sample is least due to the presence of homogenous single phase. Corrosion rate of Pearlitic microstructure is highest (In annealed and normalized samples) due to the formation of microcell between Ferrite and Cementite. Corrosion behavior of this steel in sea water and Boric acid is in accordance with the behavior reported by Sami I. al-rubaiye et al.[4],[5] Figures 1 & 2.

The corrosion rate obtained for annealed sample is 1.103 mpy. The corrosion rate obtained for normalized sample is 1.247 mpy. The corrosion rate obtained for oil quenched sample is 1.173 mpy. The corrosion rate obtained for water quenched sample is 1.040 mpy.

3.3Linear Polarization Resistance test results in Hydro chloric acid

Strong acids corrode metals very quickly particularly at higher concentration [6]. A reverse trend of corrosion has been observed in the case of these strong acids. Martensitic microstructure shows higher corrosion rate as compare to Pearlite. At higher concentaration of strong acids (such as HCl), not only general corrosion occurs but also Pitting participate in overall corrosion. In this case Martensite which has high overall energy (Nonequilibrium microstructure) corrodes at faster rate as compare to Pearlite, which is the most stable of all these. Corrosion behavior of this steel in HCl is in accordance with the behavior reported by David Abimbola Fadare et al.[6] can be seen in Figure-3.
Corrosion behavior of Annealed sample is 152.1 mpy
Corrosion behavior of

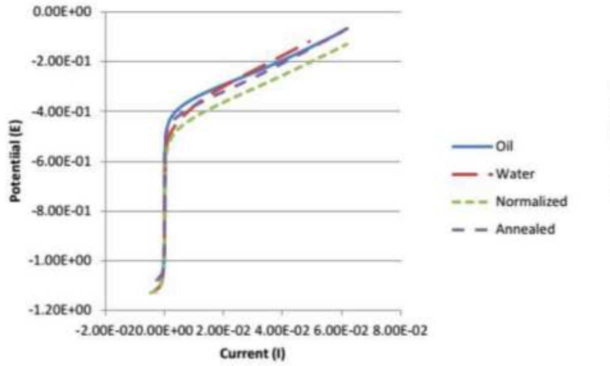


Figure 1. Comparison of all samples tested in seawater

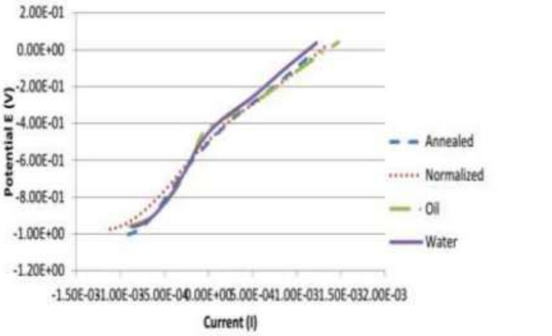


Figure 2. Comparison of all samples tested in Boric acid.

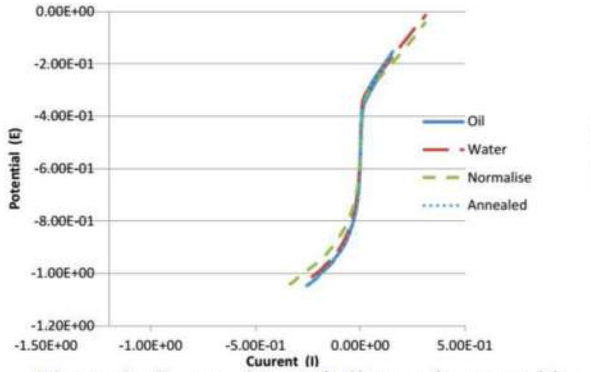


Figure 3. Comparison of all samples tested in Hydro chloric acid.

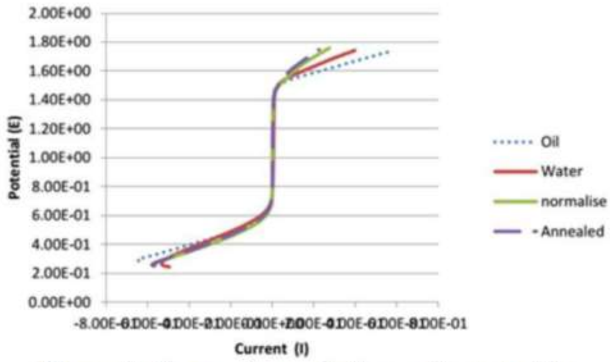


Figure 4. Comparison of all samples tested in Hydro chloric acid.

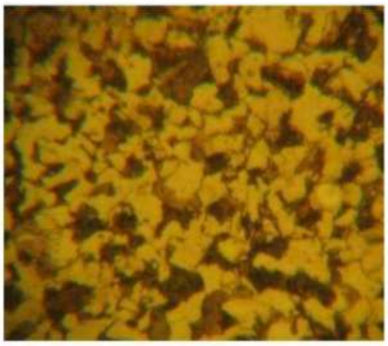


Figure 5. Microstructure of annealed sample at 400x.

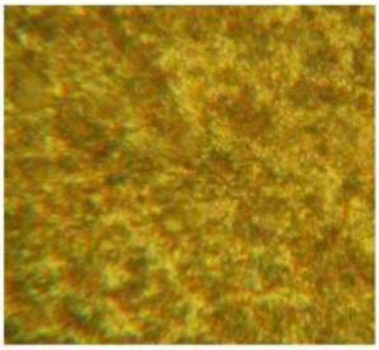


Figure 6. Microstructure of normalized sample at 400x.

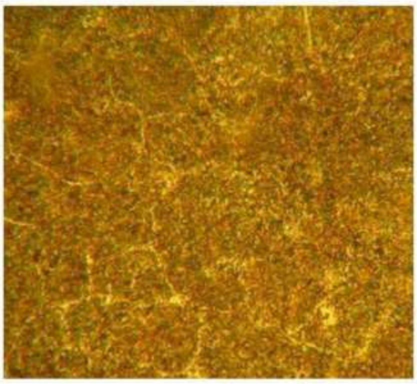


Figure 7. Microstructure of Water quenched sample at 400x.

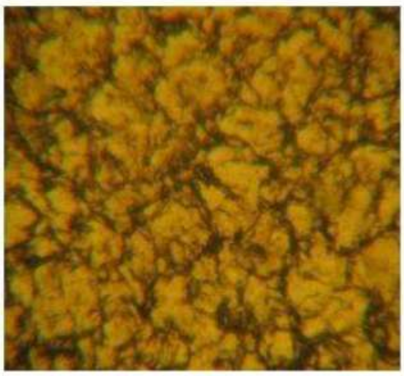


Figure 8. Microstructure of Oil quenched sample at 400x.

Normalized sample is 155.8 mpy Corrosion behavior of Oil quenched sample is 199.6 mpy Corrosion behavior of Water quenched sample is 164.3 mpy

3.4Linear Polarization Resistance Test Results In Nitric Acid

HNO3 is a very stong oxidizing agent and hence most corrosive environment among all tested [7]. Corrosion trend is similar to the behavior exhibited in HCl (Both are strong acids). Martensite has been corroded at faster rate as compare to Annealed microstructure. Figure 4 shows comparisn of all samples tested in hydrochloric acid.

Corrosion behavior of Annealed sample is 158.9 mpy Corrosion behavior of Normalized sample is 162.9 mpy Corrosion behavior of Oil quenched sample is 245.2 mpy Corrosion behavior of Water quenched sample is 185.6 mpy

3.5Microstructural Analysis

Annealed Microstructure The microstructure reveals coarse pearlite in black regions and ferrite as white regions after etching with 1% Nital, as shown in Figure 5.

Normalized Microstructure The microstructure in Figure 6 reveals pearliteferrite regions in a much finer scale as compare to Annealed microstructure, as the cooling rate is high in normalizing

Water Quenched Microstructure In the Water quenched microstructure small needle like micro constituent phase, called Martensite is present within the matrix of Ferrite, as can be observed in Figure 7. Etching was done with with nital 1%.

Oil Quenched Microstructure In oil quench microstructure Martensite is formed in small fraction due to the use of oil as quenching media, since oil has less quenching severity than water. This less severity causes yield of fresh Martensite to disrupt. It is important to note here that the presence of Bainite and tempered Martensite in the microstructure cannot be overruled Figure-8.

4 Conclusion

Conclusion of above work can be stated as follows: Corrosion rate of Martensite is least in sea water and weak acids, as it is a single phase structure, fine pearlite which makes very strong microcells corrodes at highest rate in these environments. In strong acids, corrosion rate of Martensite is highest due to being most unstable and nonequilibrium phase. With general corrosion these strong acids may cause Pitting, that accelerates the corrosion rate. In strong acidic environments Pearlite shows lesser corrosion rate. HNO3 is more corrosive to Carbon steels than HCl.

Acknowledgements

Authors would like to thank every individual who provided his assistance during any phase of this research and particularly to Mr. Zeeshan Hassan who as a Technician at Materials Deterioration lab, Department of Metallurgical Engineering, provided his assistance on numerous occasions.

References

[1] Sami I. Al-rubaiey, Eman A. Anoon, Mahdi M. Hanoon, The Influence of Microstructure on the Corrosion Rate of Carbon Steels, Eng. &Tech. Journal, Vol. 31,Part (A), No.10, 2013

[2] Injeti Gurrappa, Guntupalli Malakondaiah, Effect of environment on corrosion characteristics of newly developed DMR-1700 structural steel lop publishing science and technology of advanced materials sci. 9 (2008) 025005 (7pp) Published 12 June 2008.

[3] C. Andrade and C. Alonso, On-site measurements of corrosion rate of reinforcements

Construction and Building Materials, Vol. 10, NO. 5, pp. 315-328, 1996 Copyright 8 1996 Elsevier Science Ltd.

[4] A. M. Ramirez-Arteaga, An Electrochemical Study of the Corrosion Behavior of a Dual Phase Steel in 0.5m H2SO4 International Journal of Electrochemical science, Int. J. Electrochem. Sci., 5 (2010) 1786 – 1798

[5] R. Whinston Revie, Corrosion and corrosion control, Wiley,2015 page-143

[6] David Abimbola Fadare, Corrosion Resistance of Heat-Treated NST 37-2 Steel in Hydrochloric Acid Solution Journal of Minerals and Materials Characterization and Engineering, 2013, 1, 1-7 [7] Osarolube, E., Owate, I. O. and Oforka, N. C. Corrosion behaviour of mild and high carbon steels in various acidic media, Scientific Research and Essay Vol.3 (6), pp. 224-228, June 2008 ISSN 1992-2248 © 2008.

Reinforcement Drawings and Detailing

Engr. Sheik Shahid Iqbal
Ssi_ace@hotmail.com

This article summarizes salient requirements of reinforcement drawings and allied matters, such as responsibilities of the detailer, reinforcement billing (calling), reinforcement detailing, concrete cover requirements, reinforcement bars lap splicing etc.

1.1 Reinforcement and Placing Drawings

A Reinforcement (Engineering / Structural) Drawings

Reinforcement (Engineering / Structural) drawings are important part of the project design documents. They show:

- The reinforcement requirements of the structure and components in detail (rather than indicative as in tender drawings),
- Features like the openings (location and size), joints, block-outs, embedded metal in first stage concrete etc which influence the reinforcement placing and detailing; are copied from the concrete outlines / formwork (Source View) drawings, omitting the description, purpose of opening, or other narration (e.g. Relief Valve Support, Control Gate Dogging Device, HVAC, Fire Water, Pressurized Oil Pipe etc), and general dimensions.
- All salient elevations (top of raft, floors, landing, walkway etc; and bottom of sump and openings), in plan view and cross sections,
- Reinforcement details at / around all defined joints (construction or movement), also show water-stop – if provided in the joint.

- Reinforcement splice location, type [overlapping, couplers or welding], overlapping length of bars etc,

Reinforcement details provided on the reinforcement (engineering / structural) drawings shall be sufficient to enable subsequent preparation of placement drawings, bar bending schedule (BBS) and quantity estimates; without recourse to the designer or the detailer.

(I) **Starting a Reinforcement Drawing:** (a) – Before 'billing' (calling reinforcement on drawing) the responsible person must obtain sketches of reinforcement details, relevant notes, list of 'Reference Drawings' etc; from the design engineer.

(II) **Calling the Reinforcement:** (a) – In general reinforcement bar is called twice on the drawing elsewhere only mark number is given (b) – This facilitates verification of the design reinforcement during construction or preparation of bar schedule (BBS), which is important. Bar is called once in the main view (say plan view) with the number of bars [e.g. 12Y20-200 i.e. 12 bars Y20 (#6) at 250mm c/c, or 10Y25 i.e. 10 bars 25mm (#8) (in beam)]; and repeated in another view (cross section).

(III) **Verification of Design Reinforcement:** Sometimes an indicative (brief) BBS is provided on the reinforcement drawing covering the salient bars. In this case, the needed verification of reinforcement is made from the BBS.

B – Placing Drawings

(IV) **Definition:** as per ACI 315-01, placing drawings are working drawings that show the number, size, length, and location of the reinforcing steel necessary for the placement and fabrication of the reinforcement bars; and comprise plans, details, elevations, bar bending schedules / material lists, BBS.

(V) **Contents:** Placing drawings show reinforcement placing in the structure, joints and/or junctions in greater detail, than reinforcement detail drawings. Specific mark number (Bar Mark) is assigned to each reinforcement bar – for preparing bar list (bar bending schedules / BBS), number of bars in a given range, size of bars, indicative shape etc is generally also shown. Placing drawing is developed from an engineering (structural) drawing, generally prepared by the civil contractor at the construction site, and submitted along with a bar list (BBS) to the consultants for approval before reinforcement fabrication (cutting and bending). In some cases the design consultant prepares the placing drawings and BBS for issuance to the contractor. Placing drawing contains more elaborate details and views drawn to facilitate verification of reinforcement details, facilitates ease in visualization of correct bar shape, and drawing the shape of each bar for preparation of BBS. Placing drawings and bar lists must show all bar dimensions as out-to-out with bar lengths.

(VI) **Mark Numbers:** Bars on the placing drawings are assigned mark numbers according to the logical order of placing the bars into the structure. A bar (of a given mark number) is called once on the plan or section with the number of involved bars (or range of bars) visible there (e.g. [35] 15Y25-200 i.e. [Mk] No Bar size-Spacing), and generally repeated in another view for verification (number and diameter of bars). Elsewhere only the mark number is given. Where BBS accompany the drawing / is drawn there, detail may be provided in one view only and needed verification is made from the bar list (BBS).

1.2 Essentials Requirements of Reinforcement Drawings

In a good reinforcement drawing the following requirements and provisions are generally complied. ACI 315 contains more elaborate details on this.

1 **Compliance with Design Requirement:** Reinforcement shown tally with the detailed design requirements, given in the reinforcement sketches made by the structures design engineer.

2 **Placing:** Bar placing must be correct.

3 **Particular Locations:** Joints, block-outs, openings and points of probable stress concentration require special attention in bar detailing.

4 **Bar Diameters:** To curtail materials wastage, number of bars of different diameters may be as few as possible, Use bar combinations.

5 **Splice Length:** Lap splicing length of bars in each type of member (compression or flexural), is okay. Where seismic bending (flexural) moment in columns may be high, the splice length is based on tension.

6 **Splice Location:** In beams and other flexural members (a) – Bars are not spliced at point of maximum stress, (b) – Laps are staggered. (c) –In continuous beams no overlapping of bottom bars is made at the middle of span, or of top bars at the center of the support.

7 **Reinforcement Curtailment:** Curtailment (I) – Not only result in savings in reinforcement quantity, (II) – Help in utilization of shorter pieces of bars, (III) – Reduces congestion at beam-column junction where bars from transverse beams are also often present. (IV) – Reinforcement curtailment must conform to the standard rules.

8 **Bar Anchorage in Cantilevers:** Sufficient anchorage and counterbalance is provided to bars in cantilever members. In cantilevers, in principle the (rear / counterweight) structure mass should adequately balance the moment (torsion) at the encastre (fixed support) with good margin of safety. This balance is realized by adequate anchorage of the main (top) bars into the supports.

9 **Minimum Reinforcement:** Main and distribution reinforcement meets the minimum requirements criteria detailed later in this chapter.

10 **Stirrups / Links in Beams:** (a) – The spacing of shear ties (stirrups) in beams of frames (not in buildings in zone of moderate seismic risk) should not exceed 0.5d (d = effective depth) or 600 (24 in), nor (b) – The bar diameter be lesser than 10 (#3) as per ACI 318-08.

Note: Chinese and British codes permit use of Y8 (#2.5) bars in links in beams. Considering ACI 318-08 provision, it seems more feasible to limit the use of Y8 bars in small span beams or small structures.

11 **Column Ties:** In columns of frames not in buildings in

zone of moderate seismic risk, the tie bars shall be minimum:

- Size Y10 (#3), and
- Ties spacing not exceeding (a) – 16 x main bar diameter, (b) – 48 x tie bar diameter, or (c) – Least lateral dimension of the column.

12 **Maximum Diameter of Bar in Ties:** In the table under 3.7 – Detailing to Fabricating Standards, in ACI 315, diameter of bend for bars larger than Y25 (#8) is not given for ties. It is inferred that theoretically the upper limit to diameter of bars (for shear tie or stirrup) is 25mm (#8).

13 **Concrete Cover to Reinforcement:** Specified concrete cover is to be adequate (as per Code) and practically feasible (for the given section).

14 **Scale:** Reinforcement details are drawn to standard scale(s).

15 **Cross References:** Necessary cross-reference to architectural or formwork (concrete outline) and E&M drawings is provided.

16 **Relevant** explanatory notes are provided.

17 **Billing Pattern / Style:** See later.

1.3 Responsibility of the Engineer and Detailer

1.4

The end product of reinforced concrete engineering designs is structural drawings and specifications. A rightly detailed structure will have considerably improved serviceability and durability and minor design deficiencies may not appear or be reflected in the in-service condition.

The design engineer must furnish clear statements of the reinforcement design requirements, and incorporate the applicable design code requirements in the form of specific reinforcement details shown or notes for the detailer to follow, rather than refer to the code provision.

The detailer must ensure compliance with the engineering and detailing requirements according to the provisions given in the applicable code, in preparing placing drawings, and needs to carry out all instructions on the contract documents.

1.5 Billing Pattern

Billing: Calling a reinforcement bar on structural drawing is termed as billing. Method / style of calling bars on the drawing (billing) should be consistent or identical in a set of drawings. Following examples is provided.

15#6-12 Meaning 15 #6 (¾") bars at 12 inch center to center 15Y20-300 Meaning 15 No 20mm bars at 300mm c/c. ½"fi at 6"C/C Meaning ½" diameter bars at 6 inch center to center 25-½"AT8"C/CMeaning 25 bars of ½" diameter at 8 inch on centers [38]-27Y25 [Bar Mark No 38], 27 No 25mm bars,

Range: The applicable range of each bar is shown, and the billing detail is entered above the range line. A bold dot or small slash is used.

Uniform Pattern / Style: Uniform or identical style of billing must be used on reinforcement drawings. Bar calling style should be uniform and consistent, and not differ from drawing to drawing [e.g. Y28-250, Y28@250, Y28at250, Y28@250C/C,].

1.6 Bar Marking on Drawing for BBS

In case a bar list (bar bending schedule BBS) is provided with placement or engineering drawing, the bar mark numbers and range is given on the drawing. A bar with specific mark number (say [27]) is called on main plan or elevation with the number of bars e.g. [27] 15#6-10 [or [27] 15Y20-250] and repeated at least once in another view (e.g. section), for verification. Elsewhere only mark number is indicated. The following general rules may be followed when assigning bar marks.

1 Mark number is assigned to a set of drawings, for a defined structure (or component of large structure) starting from No 1.

2 Mark number should be assigned according to the logical sequence of bar placing in the structure,

[In case of a high retaining wall to be constructed in defined 'lifts', the vertical and horizontal bar's mark numbers may be assigned lift-wise].

3 Bars identical in shape and of same diameter, but placed at different locations (lifts) may be assigned different mark numbers.

4 For subsequent insertion of new bars at their logical (mark) number in the BBS, the bar marks should be gap numbered, to enable insertion of new bars numbers without needing to modify the assigned mark no.

[Leave three to four mark numbers unused in ten bars].

5 Mark number is generally written in circle or parentheses.

6 Even when a specific mark number is not used it must be entered in the BBS with hyphen (no entry) in shape and other columns.

7 Do not start the mark numbers from [01] in every drawing of a set of drawings covering a specific item. Preferable approach may be to start from [101], [201] etc.

1.7 Proof Reading of Drawing and BBS

After the reinforcement placing drawing is ready and generally checked, proof reading of bar list (bar bending schedule / BBS) with reference to the drawing is a necessary crosscheck.

1.7.1 Bundled Bars

When it is not feasible to place the designed reinforcement in the member economically or efficiently in layers as normal, reinforcing bars may be bundled for saving in space (between bars) to facilitate concrete placing. Recommendations provided for bundled bars in ACI 318 summarized below.

1 Bars to be Tied: Bundled bars should be tied / fastened together.

2 Limitation on Number: (a) – Not more than four bars to be placed in a bundle. (b) – Bars larger than 35mm (#11) may not be bundled as tensile reinforcement in beams.

3 Splice Staggered: Individual lap splice within bundle may be staggered.

4 Concrete Cover: Cover (= $2d_b$ or $2.5d_b$) is based on equivalent bar diameter (d_b) of the bundled bars. Generally the minimum concrete cover for bundled shall be 50 (2 in).

5 Development Length: Development length of bar within a bundle in tension shall be that for the individual bar, increased 20 percent for 3 bar bundle and 33 percent for four bar bundles, as per ACI 12.14.2.2.

6 Spacing of Bundles: The minimum clear space between bundles shall be equal to the diameter of a single, round bar having area equivalent to the area of the bundle. For bridge design, the AREMA design manual and the AASHTO bridge specifications require a minimum spacing equal to 1.5 times diameter of a single, equivalent area bar.

1.7 Concrete Cover to Reinforcement

1.7.1 Factors Influencing Concrete Cover

Concrete cover to reinforcement is required for reinforcement bond with concrete, protection against reinforcement corrosion, and fire resistance.

A - **Type of Member:** Examples includes:

- Components of building's superstructure, e.g. topping in waffle slab, solid slabs, beams, girders, columns, lift well, retaining walls in dry etc,
- Foundation: Raft, mat, footings, pile caps, laid on blinding concrete;
- Underground elements like concrete piles, structure components wherein concrete may be poured in direct contact with the ground.
- Liquid retaining, environmental engineering and hydraulic structures,
- Massive concrete structural components as in hydropower projects,
- Offshore structures exposed to wave action, and corrosive environment,

- Pre-cast concrete elements constructed under plant control conditions,

B - **Conditions of Exposure** Document BS 8110 Structural Use of Concrete, classifies structures exposure in the in-service conditions in following categories:

- Mild Elements of normal building

- Moderate Concrete in contact with potable water or non-aggressive soil

- Severe Surfaces exposed to severe rain, alternate wetting and drying,

- Very severe Off-shore structures,

- Extreme Concrete surface exposed to abrasive action from moving vehicles & like.

- Extreme Concrete surface exposed to abrasive action from moving vehicles & like.

- Criteria requirement for concrete cover is given for each exposure condition in the British and ACI standards, Chinese document 'DL / T 5057-2009 Design Specifications for Concrete Hydraulic Structures, detailed later.

C - Fire Resistance

Resistance to fire depends on (I) – Member thickness, (II) – Concrete cover (III) – Aggregates and (IV) – Finishes provided. In general minimum resistance to fire of 2 to 3 hours should be there in particularly public building structures. Cover thickness in excess of ordinarily specified value may be required especially in floors, roof slab and walls.

Table 1.8.1-C Minimum Dimensions (mm) for 3 Hours Fire Resistance

Component / Item	Slab	Beam	Column
Member min dimension	150	250	400
Min required Cover	25	55	60
Aggregate type	Normal	Normal	Normal

Elements protected by cement, gypsum or similar plaster, durable finishes or coatings (brick cladding, marble, ceramic tiles etc) will need lesser cover.

Components of environmental engineering structures (water tanks, culverts, retaining walls etc), irrigation structures (regulator, siphon etc) and hydraulic structures (barrages, tunnel / power channel intake structures, powerhouse etc); generally has no finish or coatings provided on the concrete surface. The clear concrete cover may be based on the provisions of the USACE Engineering Manual EM 1110-2-2104 – Strength Design for Reinforced Concrete Hydraulic Structures, and ACI 350R, detailed later.

D - Maximum Size of Coarse Aggregate (MSA) and Bar Diameter

Ref [1] / ACI 318-08 recommendations for concrete cover summarized later specify different cover for two categories of bar diameters and exposure conditions. In massive structures, concrete mix is proportioned for larger size of aggregates to save cementing material requirement. Cover to be 1.5xMSA.

1.7.2 General Guidelines for Concrete Cover Requirements

For cast-in place building construction, general guidelines for concrete cover are summarized below:

1 Minimum value specified in the local Building Code,

2 Cover required against specified fire resistance,

3 Cover = d_b in beams with one or two layers of reinforcement, (preferably 1.5xd_b in wide and shallow beams with two or more layers of main reinforcement),

4 2.5d_b (d_b = diameter of bar), or equivalent diameter of the bundled bars up to #11 (35mm) (limited to 60mm),

5 1.50*maximum size of aggregate (MSA) in general,

6 4/3*MSA for horizontal bars of vertical mesh (e.g. RC walls),

7 As per ACI 318-01 building structures (see later),

1.7.3 ACI 318-01 (Ref [1]) Recommended Values

A) For in-situ construction (values in mm)

• Concrete cast against & permanently exposed to earth 75

• Concrete exposed to earth, water or weather

-Larger than 16mm bars 50

-16mm and smaller bars 38

• Concrete not exposed to weather or in contact with ground (slab, walls etc) 20

• Concrete exposed to weather or in contact with ground.

-Beams, columns Primary reinforcement 50

- Stirrups, spiral, ties 38

Cover to bars in environmental engineering structures shall conform to ACI 350R-95, wherein the minimum specified concrete cover is 38mm.

1.7.3 USACE Provision for Concrete Cover in Hydraulic Structures

Provisions contained in the US Army Corps of Engineers (USACE) engineering manual 'EM 1110-2-2104 – Strength Design for Reinforced Concrete Hydraulic Structures' for irrigation and hydropower related (massive) hydraulic structures are summarized below.

• Minimum cover for reinforcement of spillway slabs and channel lining slabs on grade greater than 600 (24 inches) to be 100.

• Concrete cover based on member dimension.

Member Dimension (mm)	Concrete Cover (mm)
> 300	75
> 600	100

• In no case shall the cover be less than:

-1.50 times the maximum size of aggregate (MSA), or

-2.5 times the maximum diameter of reinforcement,

• When parallel reinforcement is placed in two layers the clear distance between layers should not be less than 150 (6 inches).

1.7.4 Considerations for Crack Control

In a well-designed beam, flexural cracks are fine and generally not visible. Nor they cause corrosion of reinforcement. As loads are gradually increased above the cracking limits, both the number and width of crack increase, and at service loads level a maximum width of crack of about 0.25mm (0.01 in) is typical. If the loads are further increased, crack width increases further, although the number of cracks is more or less stable.

Experimental studies have shown that both the crack spacing and crack width are related to concrete cover (dc) measured from the center of the bar. In general increasing the cover, results in increased spacing and width of crack. The detailer should therefore specify only deformed bars as required by ACI, and ensure that the crack width remains within the specified limits, if the intent is to specify cover in excess of the minimum code limits. Recommendation on permissible crack width is provided in the report of ACI Committee 224 – Control of Cracking in Concrete Structures and reproduced in table below.

Table 1.7-4 – Tolerable Crack Width for Reinforced Concrete.

Exposure conditions	Tolerable crack width (in)	Tolerable crack width (mm)
Dry air / protective membrane	0.016	0.41
Humidity, moist air, soil	0.012	0.30
Deicing chemicals	0.007	0.18
Seawater & seawater spray; wetting & drying	0.006	0.15
Water retaining structures	0.004	0.10

1.7.5 Actual Size of Deformed Bars

Owing to the deformations provided on the bar, its actual size is somewhat more than the nominal diameter, reproduced here from Institute of structural Engineers UK document Standard Method of Detailing Structural Concrete.

Table – Nominal and Actual Sizes of Deformed Bars (mm)

Nominal Bar Size	6	8	10	12	16	20	25	32	40
Actual Bar Size db	8	11	13	15	19	23	29	37	46

1.7.6 Upper limit to Concrete Cover

In principle larger cover gives more fire resistance and is better. However, too large cover in columns result in reduced effective width; and in beams reduced effective depth, and may also cause appearance of cracks wider than may be structurally acceptable. Upper limit posed on clear concrete cover may be the tolerable crack width for reinforced concrete detailed above.

1.8 Reinforcement Bar Splicing (Joining)

1.8.1 General Requirements

General requirements include that the choice of the type of splicing is correct, and the lap splicing length of bars in each type of member conforms to the Code requirements. In flexural members where bars are overlapped for splicing, (a) – Overlap length should be sufficient, (b) – Laps should be staggered, (c) Not more than 50 percent bars shall be spliced at one location, and (d) – Splicing is not made at the location of maximum flexural stress, In columns however it is usual to provide laps at one location (generally the floor slab top level, preferably at the middle of storey height).

1.8.2 Lap Splicing

- This is more common, easier rather more economical method of splicing one bar with the other up to 35mm diameter (#11). In view of the relative ease and speed with which lap splicing can be done, and less limitation on employing this method, bars splicing practice is adopted worldwide.
- Upper Limit to Bar Size: ACI 318 disallows splicing the reinforcement bars in tension by overlapping for diameters larger than 35mm (#11).
- Other Limitations: Document DL / T 5057-2009 'Design Specification for Hydraulic Concrete Structures' issued by the National Energy Administration of the Peoples Republic of China, states 'For axial tension members, tension members with eccentricity and structural members subjected to vibrations, lap joints shall not be adopted'.

- Splice Length: Lap splicing length of bars depends on quite a few factors as discussed later under "Lap Splicing Length"

- Nature of Stress in Member: Inclusion of seismic forces may induce considerable flexural tension in compression members.

1.8.3 Welded Splicing

General: Welded splicing method needs more careful design (for flexural members), better worker skill, and generally greater effort (in shaping bar ends for butt splices), and is applied less frequently.

Welded Splice: 'Welding of reinforcement should be avoided wherever possible' (ISE UK document). Considering the overall cost (accessibility to welded splice location and mobilizing the equipment, shaping the bar ends, welding time, specified welded joint efficiency), welded splicing method is less advantageous for smaller bars and more feasible for larger bars. As per ACI 318, welded splice is mandatory for bars larger than 35mm (#11). In some cases – due to the probable reinforcement congestion, larger bar diameter or other considerations, welding may be more suitable method for splicing. In the construction of five 12.8m (42ft) at upstream and 11m (36ft) at downstream, internal diameter, diversion, power and irrigation tunnels with more than 150m (492ft) high Gate Control Shafts provided on each, at the Tarbela Dam Pakistan, thousands of tons of #14 (45mm) and #18 (57mm) bars were weld spliced at difficult locations in circular tunnels and transition block (forming gate shaft base). Each welded joint generally required more than half an hour – excluding time needed for subsequent stress relieving (first heating the joint and allowing gradual cooling) of #14 and #18 welded bars.
[Note: AWS specifications require stress relieving of joints in plates and bars 40mm (1.5in) or more in thickness or diameter].
Standards: Welding of reinforcing bars shall conform to 'Structural Welding Code for Reinforcing Steel' ANSI / AWS D1.4 of the American Welding Society (AWS), AWS D 1.1-2000, BS EN 287-1[25], BS EN 288-3[26], or equivalent standard. ASTM reinforcing bar specifications, except for ASTM A 706, shall require a report of material properties

necessary to conform to requirements of ANSI / AWS D1.4. Weld-ability of the steel is based on its chemical composition or carbon equivalent (CE). Both grade 275 (Gr. 40) and grade 425 (Gr 60) bars conforming to ASTM A 615 can be welded. Chemical analysis is necessary to ensure weld-ability.

Use of Cold Worked Steel Bars: 'Some engineers avoid welded splice of cold worked bars, fearing reversal to mild steel. This is not true for the time and temperature associated with welding'. These remarks contained in the first edition (1989) of ref [11] of the Institution of Structural Engineers UK, are omitted in the third edition (2005). From this, the author infers that the welding of Cold Worked Steel bars is to be avoided.

Welded Joint Efficiency: 12.14.3.2 of ACI 318 requires 'A full mechanical splice shall develop in tension or compression, as required, at least 1.25fy of the bar' to ensure sufficient safety margin in the welded splice. Many specifications requires efficiency of welded joints = 125 percent in flexural members, if the welded splices are not staggered. Depending on the actual required welded joint efficiency, welded splices can require up to 25 percent more reinforcement in flexural members. Only properly qualified welders may carry out the welding of full strength joints in reinforcement.

Weld Joint Methods: Document DL / T 5057-2009 'Design Specification for Hydraulic Concrete Structures' issued by the National Energy Administration of the Peoples Republic of China, states, 'Welded joints with the bar diameter d ≤ 28mm should adopt the flash butt welding or overlap welding; and welded joints with the bar diameter d_b > 28mm should adopt the rod welding, with the cross-sectional area of the rod 1.5 folds of the cross-sectional area of the reinforcing bar. Rod welding shall not be adopted for steel bars with different diameters. Overlap welding and rod welding joints should adopt double-faced welding seam, the lap length shall not be less than $5d_b$. When single-faced welding seam is adopted because of tough welding conditions, the lap length shall not be less than $10d_b$.

- Metallic arc butt-weld with double-V is rather more time consuming but quite common in welding of large diameter bars e.g. 57mm (#18).
- Statement in Document DL / T 5057-2009 'Design Specification for Hydraulic Concrete Structures' issued by the National Energy Administration of the Peoples Republic of China, reads "Welded joints with the bar diameter d ≤ 28mm should adopt the flash butt welding or overlap welding; and welded joints with the bar diameter d > 28mm should adopt the rod welding, with the cross-sectional area of the rod 1.5 folds of the cross-sectional area of the reinforcing bars.
- The detail followed by the Chinese EPC Contractors working on hydropower projects in north of the country generally adopts overlap welding i.e. bars to be joined have min $12d_b$ lap, of which $10d_b$ is welded on one side. This approach (one side welding) is more suited at locations where access to welded bars is difficult.

1.8.4 Mechanical Connections (Couplers)

Mechanical connections (couplers), is another standard method of splicing and generally applied where other methods may be impractical or not feasible due to corrosive environments. Use of couplers is particularly advantageous in locations where long horizontal dowel bars protruding from (vertical) concrete surface, are required to remain there for long time according to the construction schedule (and welding difficult due to high humidity or other reason), e.g. dowels (for second stage concrete) of horizontal bulb turbine support girder or similar horizontal or vertical locations. Long protruding bars pose constraints on construction activity or may get rusted. Couplers provided on the bars at vertical (flat) concrete face, will facilitate subsequent connection of horizontal bars. Use of coupler may however need up to 25 percent more reinforcement. Limitations associated with the use of couplers include:

1. Method is more expensive especially for bars lesser than 25mm,
2. Effective area of threaded bars is lesser (about 0.78 times) the Ab..
3. Method needs greater skill and (usually also) time,
4. Only bars of same diameter can be coupled,
5. If the specified coupler is not manufactured locally, material procurement time (importation from abroad) may be considerable,
6. Once final, the bar diameter cannot be altered.
7. As the clear cover is measured from the outer face of coupler, clear cover requirement is fairly increased.

Couplers may be threaded or fastening type. Generally the feasible option for use of coupler in flexural members is adapted to threaded type. Metal sleeve thickness of the coupler should be included in deciding the concrete cover.

1.8.5 Cost Comparison of Reinforcement Bar Splicing Options

Comparison of the cost of reinforcement bar lap splicing with mechanical splicing (coupler connection) method shows that depending on the diameter of the spliced bar, coupler specifications, involved number of couplers (magnitude of work which is often the basis of tendered rate by the contractor), and similar factors; cost of using couplers can be about 4 to 10 times higher than lap splicing. From the experience on actual construction it is noted that it is more feasible to use couplers for splicing of bars min Y25.

1.8.6 Splicing within Bundled Bars

As per ACI 318, maximum number of bars (n) in a bundle is limited to four. Individual bar lap splicing within a bundle should be staggered. Construction considerations require stagger of lap equal to splice length, so that at no place more than (n+1) bars accumulate. Development length of individual bar within a bundle shall be increased as stated earlier.

As per ACI 318, entire bundle shall not be lap spliced (as individual bar). Ref [11] permits splicing of bundle of two bars without stagger, requiring the lap length to be based on equivalent diameter of 2 bar bundle (= $\sqrt{0.5 * db^2 * \pi}$).

1.8.7 Lap Splicing Length

Lap splicing length depends on various factors listed below. For explanation refer clause 12.2.4 ref [1].

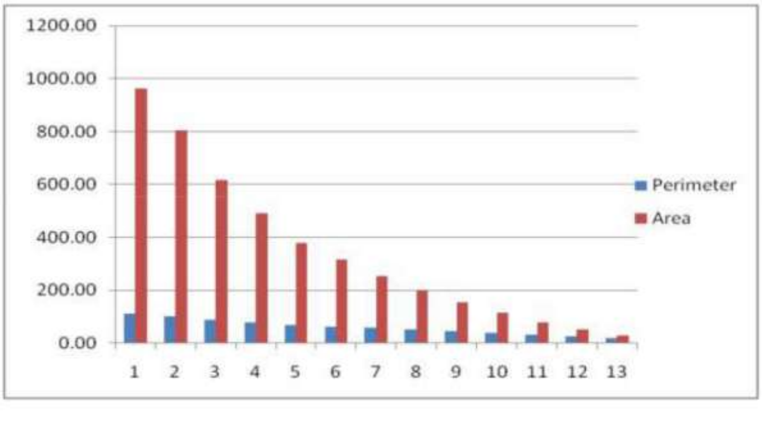
1 Reinforcement grade (*1)
2 Splice class (A, B etc) (*2)
3 Nature of stress in reinforcement (compression or tension). (Due to absence of tension cracks, lap splice length is lesser in compression).
4 Concrete type (normal or light weight). Aggregate factor λ = 1 for Normal weight concrete, and λ = 0.75 for Lightweight concrete.
5 Concrete specified strength. [Note: For concrete strength < 21Mpa (3000psi), ref [1] recommends additional factor = 1.30 to be applied to the calculated lap splice length].
6 Bar spacing and cover (Factor C applies). Ref [2] uses the terminology Categories (1 to 6), depending on:

- Type of element [longitudinal bars in beams, columns, (inner layer) of walls and slabs; other (than top) bars].
- Concrete cover (a) – ≤ d_b, (b) – > d_b, (c) – > d_b but <2 d_b, (d) – >2 d_b,
- Center to center spacing of bar 'n' (a) – ≤ 3 d_b, (b) – Equal to 3 to 4 d_b, (c) – Equal to 4 to 6 d_b, (d) – > 6d_b.

7 Bar location factor (top & other bars). Factor 1.3 is applied to splice length of top bars – where minimum thickness of concrete placed below the bars is 300 (12 inches).
8 Epoxy coated bar (bond strength is reduced because the coating prevents adhesion and friction between the bar and concrete). For epoxy-coated bars in beams factor ψe = 1.5 (If concrete cover > 3d_b or bar spacing > 6d_b ψe = 1.2). For uncoated and zinc-coated (galvanized) reinforcement ψe = 1.0.
9 Offset (space) if any, between overlapping bars; to be limited to 150mm. (The lap length may be increased by the amount of offset – maximum 150mm or 6 inch).

(*1) For grade 40 bars tension development length = fy/60, or 2/3rd of grade 60 bars.
(*2) Class A splice is one wherein (a) – The provided reinforcement is at least twice that required by design (such as at 0.25*S), and (b) – Not more than 50 percent bars are spliced at one location.

Surface and Cross Section Area of Bars: Splice length of bar is a function of its perimeter (surface area) which varies linearly with d_b. The force, which the bar can take is function of its cross sectional area (which varies in proportion to the square of d_b). If a graph is plotted for d_b against ratio of p/Ab (perimeter/area), the shape will be a curve, rather than a straight line. It implies that the splice length cannot be a linear function of diameter of bar (d_b). In view of this non-linear relationship, effect of concrete strength and other factors on the splice length, relating the splice length 'L' linearly with bar diameter 'd_b' is approximate. Chart below shows Ab and perimeter of bars.



No	1	2	3	4	5	6	7	8	9	10	11	12	13
D (mm)	35	32	28	25	22	20	18	16	14	12	10	8	6
P (mm)	110	101	88	78.5	69.1	62.8	56.5	50.3	44	37.7	31.4	25.1	18.8
A(mm^2)	962	804	616	491	380	314	254	201	154	113	78.5	50.3	28.3

The reader must understand the theoretical considerations and exercise engineering judgment in deciding calculated values of the bar splice lengths.

For reinforcement bars up to Y25 (#8) conforming to ASTM A 615 grade 275 (40) or equivalent specifications, for quantity estimation and similar purposes, for normal weight C20 (21Mpa) concrete, one may relate the splice length in terms of d_b approximately as follows or listed in the table. Not more than 50 percent bars may be spliced at one location in beams.

- Lst = Tension Lap, 40d_b up to Y20 & 50d_b for larger bars,
- Lsc = Compression Lap, 24d_b,

The tension splice length (Lst) values will:

- Reduce for higher strength concrete,
- Increase 30% for top bars (where more than 300 (12 inch) concrete is placed below the bar),
- Increase for grade 75 bars,
- Increase for bars in beams – depending on available clearance between the bars and concrete cover provided,
- Increase about 20 to 50 percent for Epoxy Coated Bars, (depending on available clearance between the bars and concrete cover),
- Zinc Coated (Galvanized) bars may be treated as uncoated, splice length will remain the same,

1.9 Reinforcement Curtailment

1.9.1 Rules for Simply Supported Beams

In a simply supported beam carrying uniform loads, the BM diagram is parabolic. The value is maximum at the center and minimum near the supports. As we move from the center towards the support, BM reduces, and longitudinal reinforcing bars can theoretically be stopped (curtailed) at the point after which the bar is no longer required. The bars are actually stopped past the theoretical curtailment point for anchorage length. General rules for curtailment of reinforcement bars are summarized below.

1. Minimum Reinforcement: At no point in the beam the amount of main (tensile) reinforcement should be lesser than 0.0015bh for grade 60 bars and 0.0025bh for grade 40 bars.

2. No Curtailment at Midspan: The bars shall not be curtailed in the maximum tension zone (midspan) in flexural members,

3. Maximum Amount of Curtailment: Total, not more than 2/3rd bars shall be curtailed in a beam as per ref [11] / BS. ACI 315-95 permits curtailment of only one-half or fifty percent bars.

4. Extension of the Bar: Each curtailed bar should extend a distance = greater of: (a) – Effective depth (d), or (b) – 12d_b (d_b = bar diameter), past the theoretical curtailment point.

5. At the Support: (a) – Anchorage is provided to minimum two bars, past the theoretical end (end of bearing on support) point (as amended in ACI 315-95 and subsequent editions), by providing a 90° bend, and extending the bar 12d_b upwards; (b) – Minimum number of bars required to bear at the support is two.

6. Bearing at Support: Minimum bearing of bars at the support = 150mm (6 in).

7. Distance from Support Face: In earlier editions of ACI 315 maximum curtailment distance specified for bars in simply supported beams = Span/8. Later editions require this to be zero. It implies that bars in simply supported beams may only be stopped at the support face.

1.9.2 Reinforcement Curtailment in Deep Beams

Definition and Considerations: When the clear span l_n (measured face to face of support) to overall depth 'h' ratio (l_n/h) is lesser or equal to five (in 1995 edition) four (in 2008 edition), beam is classified as deep beam. Stress distribution differs from that assumed in normal beams. BS 8110 does not particularly address this subject and the needed guidance is taken from ref [1]. Considerations of non linearity of strain distribution in the section, and safety against lateral buckling (of narrow deep beams), may require that the lateral supports are not spaced farther apart than 50b in narrow deep beams.

Structural Behavior: The usual hypothesis that plane sections before bending remains plane after bending does not hold for deep beams. Consequently the flexural stresses are not linearly distributed, even in the elastic range, and the usual methods for calculating section properties and stresses cannot be applied. The deflection is also limited. The flexural strength can be predicted with sufficient accuracy using the same methods as applied for beams of normal proportions. A significant part of the (concentrated) load is transferred directly from the point of application to the supports by diagonal compression struts (strut and tie action). The main flexural steel is placed near the tension edge, as usual, but special attention must be paid to the anchorage of such reinforcement, because their ultimate strength depends on strut-and-tie-action. Vertical ties are less effective than horizontal web reinforcement which act more nearly in the direction perpendicular to diagonal crack and contribute to shear transfer by dowel action.

Reinforcement Detail: Use of many small diameter bars carried full into and securely anchored at supports, and distributed over depth of (5h – l_n)/20 from soffit is preferable (h = overall depth and l_n = span of beam). At interior supports of continuous deep flexural members, negative moment tension reinforcement shall be continuous with that of the adjacent spans.

Shear strength of deep beams can be two to three times higher than may be worked by ACI code equations developed for beams of normal proportions – depending on proportions of the member. The critical section for shear is to be taken at a distance 0.15*l_n from support face in case of UDL, and 0.5a for beams with concentrated loads (a = distance of concentrated load from support face), not to exceed distance = d from support face. Unlike a normal beam – where shear reinforcement is curtailed after 0.25*l_n, in deep beams, in either case, calculated shear reinforcement is to be used throughout the span.

1.11 Reinforcement Bars Spacing

Correct bar spacing improves the structure's serviceability and can enhance its life by limiting the cracks. ACI and other references contain detailed provisions on spacing limits of reinforcement bars. Minimum limit of bar spacing is established to permit concrete to flow readily into spaces between bars and forms and to insure against concentration of bars on a line that may cause shear or shrinkage cracking.

1.11.1 Bar Spacing Requirements for Building Structures

Maximum and minimum (center to center) spacing of bars as per ref [1] and BS for different components is summarized below.

1 – Slab (Max) main flexural bars = 3d (d = effective depth) – as per BS, or 3h (h = overall depth) as per ACI. However, as per ref [1] clear spacing at critical section of two-way slabs (like the mid-span or continuous support) = 2h. As the bar spacing is maintained constant due to practical reason it implies that the bar spacing should not exceed 2h. (Max) spacing for distribution bars = 5d or 450 (18in).

2 - Wall Similar provisions apply to wall.

3 – Beam Main bars. Minimum clear spacing between main bars = greater of d_b or 25mm, if maximum size of aggregate is limited to 20mm (3/4") [preferably 30mm, considering actual outer diameter d_b(a) including deformations].

Ties or Links in beams. Maximum spacing = 0.5d or 600 (24 inch), Minimum d_b = Y10 (#3) in general, Y6 (#2) in small span lightly loaded beams (as per BS only).

[Note: 600 spacing will be practicable in beams with h = about 1300 (52 inch). Compliance with other ACI provisions will also require horizontal bars in the mid-section on either face of the beam, against shrinkage].

Limit: Maximum limit of horizontal bar spacing in tension is established to ensure acceptable crack width. British references BS 8110 & CP 110 suggest maximum clear (horizontal) distance between adjacent bars (or bundle) = 300 (12 inch).

4 – Column Minimum clear distance limitation between main bars (in spirally reinforced or tied columns) = 1.5 d_b. This limitation also apply at location of lap splices, which implies that in the general column section, clearance between bars shall be 2.5d_b (d_b = bar diameter). Clear distance between longitudinal bars in rectangular columns shall not exceed 150 (6 inch). Rectangular ties Y10 (#3), (1) – 16*d_b(m) (d_b(m) = diameter of main bars), (2) – 48d_b(t) (d_b(t) = diameter of tie bar), (3) – least lateral dimension of column.

1.11.2 Bar Spacing Requirements for Hydraulic Structures.

Document US Army Corps of Engineers EM 1110-2-2104 – Strength Design for Reinforced Concrete Hydraulic Structures contains following provisions.

The clear distance between parallel bars should not be less than 2.5 times the nominal diameter of the bars nor less than 1.50 times the maximum size of coarse aggregate (MSA). #45 (No 14) and #57 (No 18) bars should not be spaced closer than 150mm (6 inches) and 200mm (8 inches), respectively, center to center. In construction of massive reinforced concrete structures, bars should be spaced 300mm (12 inches) center-to-center wherever possible to facilitate construction. The maximum spacing of both primary (main) and secondary (distribution) reinforcement should not exceed 18 inches.

1.12 Minimum and Maximum Reinforcement Amount

A minimum amount of reinforcement is specified for all reinforced concrete (RC) structures to minimize cracking and to tie the structure together to assure it is acting as assumed in the design. Design Codes also specifies maximum reinforcement requirements to facilitate pouring of concrete.

1.13 Summary of ACI 318-08 Requirements

Following requirements for minimum and maximum reinforcement amounts apply to components of buildings. Concrete strength is based on cylinder.

Columns:

- Minimum one percent main (longitudinal) reinforcement is specified to provide resistance to bending which needs to be considered in conformance to code provisions, whether or not computations show that bending exists, and to reduce the effect of creep and shrinkage of the concrete under sustained high compressive stresses.
- Minimum number of (main) reinforcement bars in circular columns is six and rectangular columns four. Minimum diameter of main bar Y12 (#4).
- Diameter of ties in columns shall be min Y10 (#3) for main / longitudinal bars up to Y32 (#10), and spaced not more than (i) – 16 x diameter of longitudinal bar (16 d_b), (ii) – 48 x diameter of tie, or (iii) – Least lateral dimension of the member.
- Diameter of ties in columns with main bars larger than Y32 (#10) must be 12mm.
- Clear distance between alternate main bar of column be limited to 150mm (6 in) and alternate bar shall be enclosed by a 90 degrees bend. Also refer detailing of columns later in chapter 9.

Beams:

- To forestall against probability of sudden failure, ref [1] specifies that minimum reinforcement shall not be less than:

As (min) = 3(fc^0.50)/fy x (bwd) nor less than 200(bwd)/fy
Wherein bw = width of beam rib, d = effective depth.
Exception is section where the available reinforcement is more than 4/3 x As (calculated) in both positive and negative moment regions. For more details of the theoretical background / rationale of this provision the reader may refer commentary in ACI 318-08 under 10.5.2 to 10.5.4.

- Where the factored shear force Vu exceeds one half the shear strength provided by concrete ΦVc, nominal shear ties to restrain the growth of inclined cracking, is specified in ACI 318-08. Exception is slabs.
- Bar Diameter and Spacing: Minimum requirements of bar diameter and spacing shall be complied in construction drawings.

- Design Shear Force: In non pre-stressed beams, design shear may be taken the same as at d from support face (d = effective depth). This provision does not apply to members without stirrups.
- Stirrups / Links: If factored shear force (Vu) is not > [10*(fc')^0.50*bw*d], (1) – The diameter of stirrups placed perpendicular to the axis of member shall be minimum Y10 (#3), (2) – Spacing of stirrups in non pre-stressed members, shall be minimum of (a) – d/2 (d = effective depth), (b) – 600 (24 inch) and 3) – Spacing of stirrups in pre-stressed members shall be 0.75h or 600 (24 inch) refer [1], 11.5.4 – spacing limits for shear reinforcement.

[Note: If Vu > (10*(fc')^0.50*bw*d), increase the section dimensions].

- When h (overall depth) exceeds 750mm in beams, longitudinal bars should be provided on the outer faces at not more than 250.

Minimum Reinforcement Area in Slabs and Walls

Minimum area of reinforcement required by ref [1] and ref [2] in slab and wall components summarized below applies in case where shrinkage and temperature movements are permitted to occur. Deformed reinforcement conforming to ASTM A 615 or equivalent shall be provided on tension face, or otherwise half on each face, in accordance with the following, limited to Y28-300 (#9-12") on each face, in each direction.

1 Minimum ratio of As/Ag anywhere 0.0014

2 Slabs (in dry) with grade 60 bars 0.0018

3 Slabs (in dry) with grade 40 bars 0.0020

4 Walls Vertical reinforcement grade 60 bars 0.0012

5 Walls Horizontal reinforcement grade 60 bars 0.0020

6 Slabs in contact with water / ground / backfill 0.0028

7 Reinforcement in the bottom of slabs resting on ground may be reduced by 50

percent of the amount calculated by this provision

8 In no case the distribution reinforcement provided transverse to main bars shall be lesser than 0.2*As (As = area of main bars).

Minimum Shrinkage and Temperature Reinforcement (ACI 350R-08)

Length between movement joints m (ft)	Minimum shrinkage and temperature reinforcement ratio	
	Grade 40	Grade 60
Less than 6.0 (20)	0.00030	0.0030
6 (20) to < 9.0 (30)	0.0040	0.0030
9 (30) to < 12 (40)	0.0050	0.0040

Note: When using this table, the actual joint spacing shall be multiplied by 1.5 if no more than 50% of the reinforcement passes through the joint.
Concrete sections that are at least 600mm may have the minimum shrinkage and temperature reinforcement based on a 300mm concrete layer at each face. Both face bars are effective in controlling cracks

1.14 Summary of BS Code Requirements

1 If for architectural or other reason a larger column is provided than is necessary to support the ultimate load, a lower percentage of steel will suffice provided that $A_{sc}f_y$ = 0.15N (N = factored load).

2 According to BS 8110 the minimum amount of main tension reinforcement provided in a rectangular beam or slab should be 0.0024bh with mild steel and 0.0013bh with high yield steel. In slab this minimum proportion should be provided in each direction.

3 A steel area of 0.0015 times the longitudinal cross section area of flange, irrespective of the type of steel, shall be provided over the top in the full width of the flange in tee and spandrel (ell) beams.

4 In no case should the amount of either tension or compression steel exceed 0.04bh – in beams. It implies that either splices shall not be provided to main bars of beams, or the reinforcement percentage is reduced.

5 Shrinkage and temperature reinforcement is required at right angles to the principal reinforcement to minimize cracking and to tie the structure together to assure it is acting as assumed.

2.15 Use of Computer in Reinforcement Detailing

The computer system for detailing reinforcing bars has been devised to use digital computers to speed up the preparation of placing drawings, to facilitate neater and more compact drawings, which relieves the detailer of tedious and time-consuming computations performed efficiently by the computer.

Computer-aided drafting (CAD), is also used in the drawing and detailing of reinforcement / placing drawings. This system gives the detailer speed, accuracy, and an expeditious way of making changes when necessary [ACI 315]. A pragmatic approach is to draw basic bar using 'Offset' command in AutoCAD and modify the shape as needed using 'Trim', 'Fillet', 'Rotate', move of curser, or other appropriate command.

2.16 Reinforcement Drawing Checking

Checker of the drawing must ensure that the following is complied.

1. Structure dimensions, EL, location and size of openings and movement joints, waterstop etc; are consistent with Formwork drawings [Drawing is developed from one 'Source View'].

2. Requirements of good drawing are complied.

3. General quality assurance (QA) requirements are complied.

4. Essentials of Reinforcement Drawings listed above are complied. The checker may shortlist the items from 'Requirements', 'QA', and 'Essentials' for the applicable case.

5. Minimum reinforcement requirement for the specific component listed in section 6.12 is complied.

6. Checking compliance to requirement of structural integrity summarized here below from ACI 318-08 is the designers job [e.g. (a) – In beams along the perimeter of structure continuous top and bottom reinforcement provides a continuous tie around the structure. (b) – At non-continuous supports, the reinforcement shall be anchored to develop 'fy' at the face of the support using a standard hook satisfying 12.5 (of ref [1]), (c) – The continuous reinforcement required in 7.13.2.2 (of ref [1]) shall be enclosed by transverse reinforcement of the type specified in 11.5.4.1 (of ref [1]).

The transverse reinforcement shall be anchored as specified in 11.5.4.2; etc.

OSMANI & COMPANY (PVT.) LTD.

OSMANI
Engineering - Architecture - Planning - Mapping - Technology

who we are

OSMANI & COMPANY PVT. LTD. (OSMANI) is one of the leading Consulting Engineering Firms of Pakistan standing more than 55 years in the this Profession. Established in 1960 at Karachi, Pakistan, have grown from a small private group of Engineers & Architects to a large organization in the shape of Private Limited Company in 1971 employing now 600+ technical & support staff. We have our credit 5000+ prestigious projects of National & International importance spread all over Pakistan and abroad.

Provide Solutions

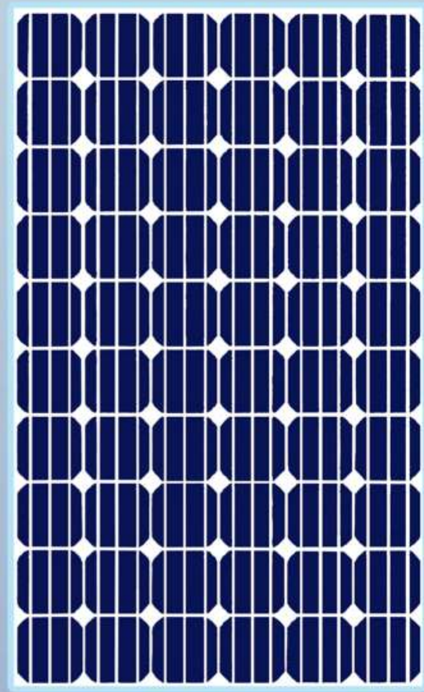
- Urban Planning, Master Planning & Structural Planning
- Preliminary Planning & Feasibility Studies
- Master Planning & Infrastructure Dev. of New Towns & Cities
- Water Treatment, Bulk Water Supply, Reservoirs & Distribution
- Sewage Treatment, Sewer Trunks Main & Drainage Systems
- Urban & Rural Freeways, Highways and Railroads
- Hospitals / Healthcare Facilities
- Large scale High-end Offices, Malls, Housing Schemes
- Interchanges, Bridges & Transportation Hubs (Airports)
- City & Town level Rehabilitation of existing Infrastructure
- Irrigation Systems, Dams, Canals, Agriculture Projects
- Power Plants, Electricity, Gas & Telecom Infrastructure
- Industrial Cities, Estates & Mid to Large Industrial Projects
- Institutional Facilities,Hospitals, Univ. & Public Buildings
- Policy Frameworks & Studies (IEEs, EIAs & Feasibilities)
- Zoos & Safari Parks, Playgrounds & Landscaping

Track Record

- DHA City Karachi
- K-IV Karachi Bulk Water Supply
- LDA Hawksbay Scheme 42 Karachi
- LDA City Lahore
- DHA Phase VIII Karachi
- Multan Metro Project (BRT)
- Faisalabad Mass Transit System
- FFBL World Class Slaughterhouse & Meat Complex
- Parliamentarian Residences for Male & Female members of provincial assembly Sindh
- Suffa University at DHA City Karachi
- 500 Beds Medical, Dental, Teaching College & Hospital at Karachi
- New 100 MGD Pumping Station Dhabeji
- ADB funded Urban Development Strategy for the city of Sukkur
- Pollution Control and STPs for CDA Islamabad
- M3 Industrial City Faisalabad
- Federal Govt. Employees Housing Scheme at Islamabad
- 250 Beds Hospital (2 Nos.) at Muzaffarabad & Rawalakot, AJK
- SWWB 4000+ Apartments, Karachi
- NHA's Larkana - Nasirabad Road
- ADB Assisted Road Project (NHA Under FERP)
- ADB Assisted Road Project in Sindh (W&S under FERP)

CREATIVE GROUP

ISO 9001 - 2008 CERTIFIED



Frp/ Grp & Epoxy Composite Pipes

Fuse Cutout & Accessories

CREATIVE ELECTRONICS PVT. LIMTED

SKYPOWER (PVT) LTD.

CREATIVE ENGINEERING PVT. LIMTED

Head Office:-160/s Q.I.E
Kot Lakhpat,
Lahore - Pakistan
Ph: 042-35118710
042-35111727
www.Creativegrp.net