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Giving Concept of an Analog Notch Filter for Removing Interference from Engineering Systems to Engineering Students

Ghulam Abbas and Muhammad Nasir Khan

Department of Electrical Engineering, The University of Lahore, Lahore 54000, Pakistan

Corresponding author: Ghulam Abbas (e-mail: engrgabbas@gmail.com)

***Abstract*—Power lines exist everywhere. Interference of power frequency with signals of other systems (telephone, music, and so on) is inevitable. This results in deteriorating the quality signals of other systems to be used for accomplishing required tasks. In this paper, a continuous-time notch filter is employed for removing the interference or annoying hums caused by the powerline frequency or its second or third harmonics in two engineering systems, namely the telephone transmission system, and the tape deck system. The notch filter accomplishes this task by attenuating the magnitude of the interference signal at a notch frequency to zero (ideally speaking). The paper may serve as a starting point for the engineering students who want to learn the basics of analog filters. MATLAB/Simulink based simulation results display that the notch filter can successfully filter out power frequency interference/hums or its harmonics to get the required quality signal at the output.**

***Index Terms*— Notch filter, telephone transmission system, tape deck, powerline frequency, harmonics.**

I. Introduction

The quality of the signals of various engineering systems deteriorates due to the interference of the powerline frequency (single-frequency interference) or its harmonics (multiple-frequencies interference). These frequency components need to be removed. One possible solution is the utilization of a notch filter to remove 50-Hz (the powerline frequency in most parts of the world, Europe, and Pakistan) or its harmonics. Conceptually speaking, notch filter removes the frequency components by attenuating their magnitudes at the required notch frequencies to a maximum without disturbing the other useful frequency components (the original information). In this paper, an analog notch filter is applied to two engineering applications for removing hums occurring at powerline frequency.

Many researchers have successfully employed a notch filter, analog as well as digital, for eliminating interference embedded with original information of the systems. A digital FIR equiripple notch filter [1], and an adaptive filter and a notch filter [2] were successfully applied for eliminating powerline interference from Electrocardiogram (ECG) signal. In [3], powerline interference cancellation was carried out by a linear Kalman notch filter. Reference [4] suggested a computationally effective solution in the form of two-pole and multi-pole notch filters for Global Navigation Satellite System (GNSS) interference detection and mitigation. Reference [5] suggested the utilization of multiple-notch filtering methods for notching harmonic powerline interference with improved transient behavior.

Other than notch filters, other filtering mechanisms are also reported in the literature. Reference [6] employed S-transform as a filter in filtering out powerline interference from biomedical signals. In [7], the ECG signal was de-noised from a 50-Hz Powerline Interference (PLI) noise by Discrete Wavelet Transform (DWT). Suppression of powerline noise from the ECG signal was also carried out using an FIR digital filter implemented with a hamming window [8] and a rectangular window [9].

In this paper, two engineering applications are considered to highlight the significance of a notch filter for removing the powerline frequency or its harmonics. Very limited research work is found in the literature where a notch filter is used for filtering out interference for the mentioned engineering systems. The other aim of presenting the paper is to make engineering students understand the basics of a notch filter and then to apply it to real engineering applications to remove powerline interference and noise.

The paper is organized in the following way. Section II describes the fundamentals of a notch filter. The considered systems, i.e., telephone transmission system, and the audio deck system are detailed in Section III along with the simulation results to validate the effectiveness of the notch filter in removing the interference. In the end, in Section IV, conclusions are deduced.

II. Analog Notch Filter Fundamentals

A notch filter is essentially a stop-band or stop-elimination filter that stops the notch frequencies and allows all other frequencies to pass. The circuit diagram of a typical notch filter is shown in Fig. 1. It consists of a capacitor and an inductor connected in parallel along with a resistor.

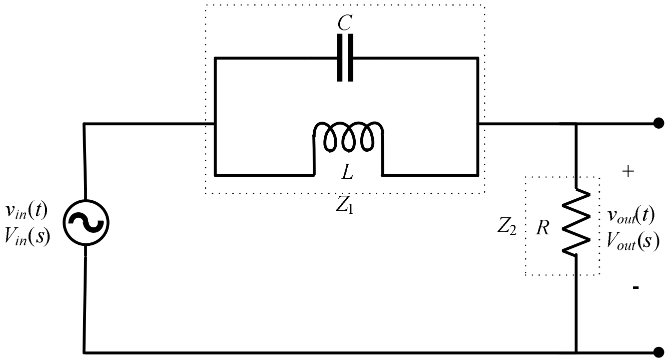

Fig. 1. The circuit diagram of a notch filter.

To get more insight into the functionality of a notch filter, we derive the transfer function of it as

$$G(s)=\frac{V_{out}}{V_{in}}=\frac{Z_2}{Z_1+Z_2}=\frac{R}{\dfrac{Ls}{s^2LC+1}+R}$$
$$=\frac{R\left(s^2LC+1\right)}{Ls+s^2LCR+R}=\frac{s^2RLC+R}{LCRs^2+Ls+R} \tag{1}$$
$$G(s)=\frac{s^2+\dfrac{1}{LC}}{s^2+\dfrac{1}{RC}s+\dfrac{1}{LC}}$$

with

$$Z_1=\frac{(sL)\left(\dfrac{1}{sC}\right)}{sL+\dfrac{1}{sC}}=\frac{Ls}{s^2LC+1}$$

$$Z_2=R$$

Replacing $s=j\omega$ gives

$$G(j\omega)=\frac{V_0}{V_{in}}=\frac{(j\omega)^2+\dfrac{1}{LC}}{(j\omega)^2+\left(\dfrac{j\omega}{RC}\right)+\dfrac{1}{LC}} \tag{2}$$

The notch filter is essentially a two-zero two-pole system. The bode diagram (the magnitude plot) is roughly sketched in Fig. 2.

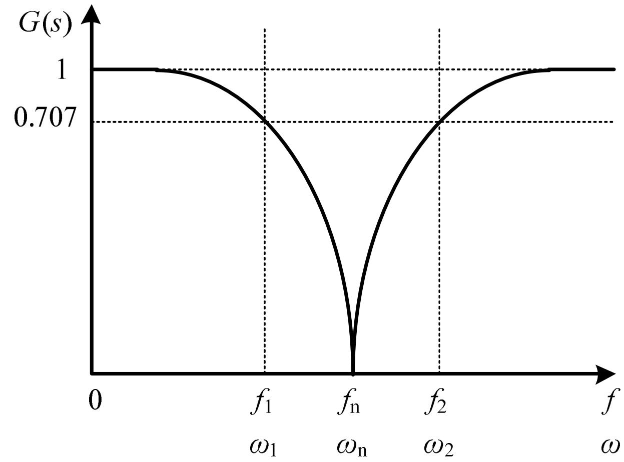

Fig. 2. Bode plot (magnitude curve) of a notch filter.

The frequencies ω_1, ω_2 and ω_n are geometrically interrelated by $\omega_1\omega_2=\omega_n^2$, whereas bandwidth BW of the filter is $\omega_1-\omega_2$. At the notch frequency $\omega_n=1/\sqrt{LC}$, the transfer function $G(s)$ reduces to zero, i.e., $|G(j\omega_n)|=0$. The magnitude curve of the Bode plot suggests that there exists a symmetry which is expressed by

$$\begin{cases}|G(j\omega_1)|=|G(j\omega_2)|\\ \theta(j\omega_1)=-\theta(j\omega_2)\end{cases} \tag{3}$$

It should be noted that the minimum the notch width is, the better the notch filter is characteristically. The filter with less notch width eliminates typically the required frequency components without reducing the magnitude of other frequency components.

III. Design Examples

In this section, the application of a notch filter to two systems, i.e., telephone transmission system and tape deck system is presented for eliminating 50-Hz interference or second or third harmonics of it.

A. A Telephone Transmission System

A telephone transmission system suffering from a 50-Hz power frequency along with a notch filter is shown in Fig. 3. Let the equivalent resistance of the telephone system be denoted by R_{eq}. The purpose of the notch filter is to filter out 50-Hz interference.

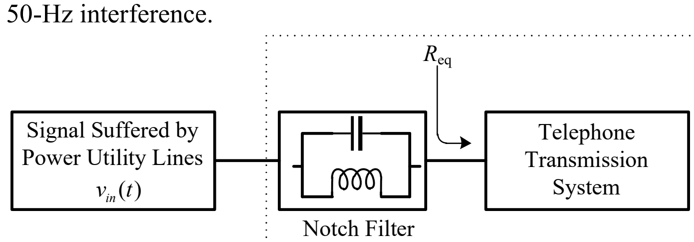

Fig. 3. A telephone transmission system suffering from a 50-Hz power frequency along with a notch filter.

By the inspection of Fig. 3, the equivalent circuit model for the telephone transmission system can be derived. It is the same circuit, as indicated in Fig. 1. It requires only the replacement of R with R_{eq}. As a result, the transfer function of the system (LC network followed by R_{eq}) is given by

$$G(j\omega)=\frac{V_{out}}{V_{in}}=\frac{(j\omega)^2+\frac{1}{LC}}{(j\omega)^2+\left(\frac{1}{R_{eq}C}\right)j\omega+\frac{1}{LC}} \tag{4}$$

For notching $\omega_n = 1/\sqrt{LC} = 2\pi(50) = 100\pi$, if we select an easily available capacitor with a standard value of 150 μF, then the value of an inductor comes out to be 0.0675 H.

The input signal to the notch filter $v_{in}(t)$ contains a sinusoid of 1000-Hz (the original telephone signal to be passed) and a sinusoid of 50-Hz (the power frequency to be stopped) and is given mathematically by

$$v_{in}(t)=\underbrace{1\sin\left[(2\pi)50t\right]}_{signal\ to\ be\ stopped}+\underbrace{0.5\sin\left[(2\pi)1000t\right]}_{signal\ to\ be\ passed} \tag{5}$$

For the sake of simplification, the magnitude of the voltage signal whether it is the original signal to be sent or the interfering powerline signal is kept unity or fraction of it, as we are more interested in notching power frequency or harmonics of it.

From the simulation result shown in Fig. 4, one can observe that $v_{out}(t)$ does not contain 50-Hz interference.

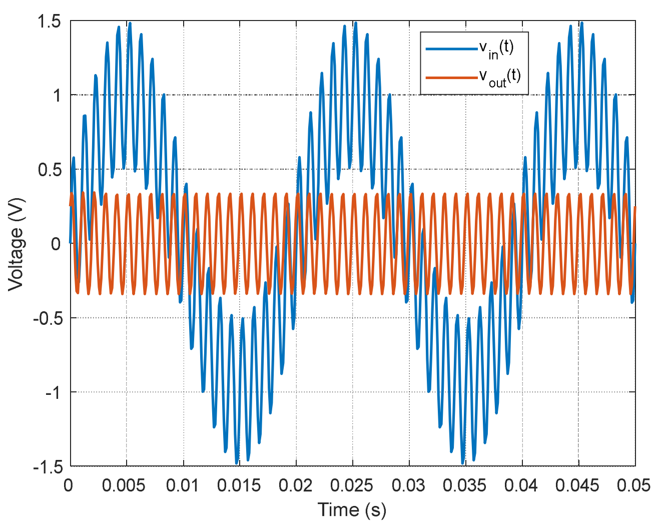

Fig. 4. The output voltage without the 50-Hz interference.

If we include the second- and third-harmonic junk in $v_{in}(t)$, then $v_{in}(t)$ takes the following form

$$v_{in}(t)=\underbrace{\begin{matrix}1\sin\left[(2\pi)50t\right]+0.3\sin\left[(2\pi)100t\right]\\+0.2\sin\left[(2\pi)150t\right]\end{matrix}}_{signals\ to\ be\ stopped}+\underbrace{0.5\sin\left[(2\pi)1000t\right]}_{signal\ to\ be\ passed} \tag{6}$$

As can be observed from Fig. 5, the same notch filter used for removing 50-Hz interference can remove second and third harmonics as well.

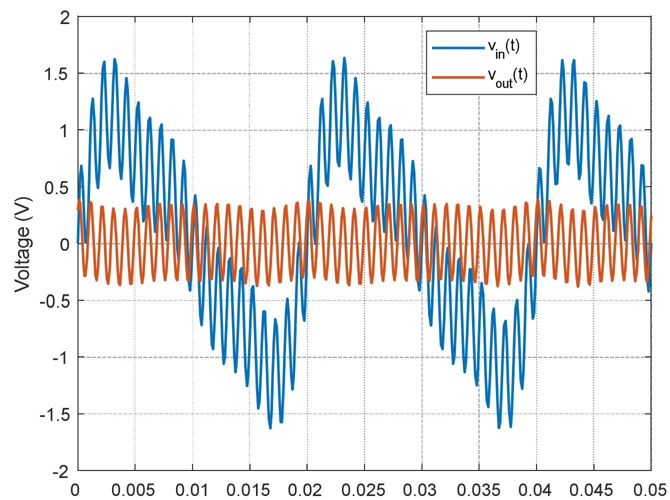

Fig. 5. Input and output voltage waveforms.

B. A Cassette Deck System

Another system, i.e., a cassette deck system, also undergoes the effect of powerline frequency of 50-Hz. Remember that Audio Frequency Spectrum (a range of audible frequencies) spans from 20 Hz to 20 kHz. A cassette deck system, if improved well, could record and play any frequency lying within Audio Frequency Spectrum. However, cheaper decks usually come without filters like MPX (Multiplex Signal) and thus are not able to remove noise to ensure better sound quality. The paper proposes a notch filter for filtering out such noise.

A cassette deck system (block diagram and circuit diagram) suffering from 50-Hz power frequency along with a notch filter is shown in Fig. 6. Let the equivalent resistance of the cassette tape player and the power amplifier with the speaker be denoted by R_{deck} and R_{amp} respectively. Their values are taken 50 Ω and 1 kΩ respectively. $v_{out}(t)$ is essentially $v_{amp}(t)$.

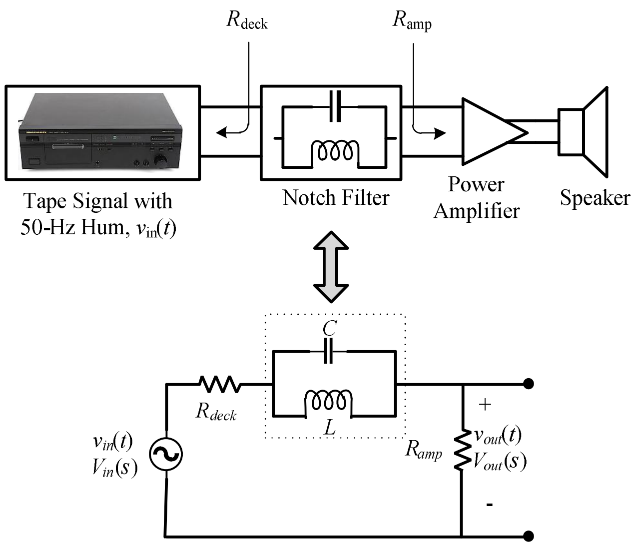

Fig. 6. A cassette deck system (block diagram and circuit diagram).

Application of voltage division rule (VDR) to the circuit shown in Fig. 6 results in the following transfer function

$$G(s)=\frac{V_{out}}{V_{in}}=\frac{R_{amp}}{R_{deck}+R_{amp}+\left(sL \parallel \frac{1}{sC}\right)} \quad (7)$$

Manipulation of (7) gives

$$G(s)=\frac{V_{out}}{V_{in}}=\frac{R_{amp}}{R_{deck}+R_{amp}}\left[\frac{LCs^2+1}{LCs^2+\left(\frac{L}{R_{deck}+R_{amp}}\right)s+1}\right] \quad (8)$$

Replacing $s=j\omega$ gives

$$G(j\omega)=\frac{V_{out}}{V_{in}}=\frac{R_{amp}}{R_{deck}+R_{amp}}\left[\frac{(j\omega)^2 LC+1}{(j\omega)^2 LC+\left(\frac{L}{R_{deck}+R_{amp}}\right)(j\omega)+1}\right] \quad (9)$$

For notching $\omega_n = 1/\sqrt{LC} = 2\pi(50) = 100\pi$, if we select an easily available capacitor with a standard value of 22 µF, then the value of an inductor comes out to be 0.4606 H.

The input signal to the notch filter $v_{in}(t)$ contains a sinusoid of 2000-Hz (the original music signal to be passed) and a sinusoid of 50-Hz (the power frequency to be stopped) and is given mathematically by

$$v_{in}(t)=\underbrace{1\sin\left[(2\pi)50t\right]}_{\text{signal to be stopped}}+\underbrace{0.5\sin\left[(2\pi)2000t\right]}_{\text{signal to be passed}} \quad (10)$$

From the simulation result shown in Fig. 7, one can observe that $v_{out}(t)$ does not contain 50-Hz interference.

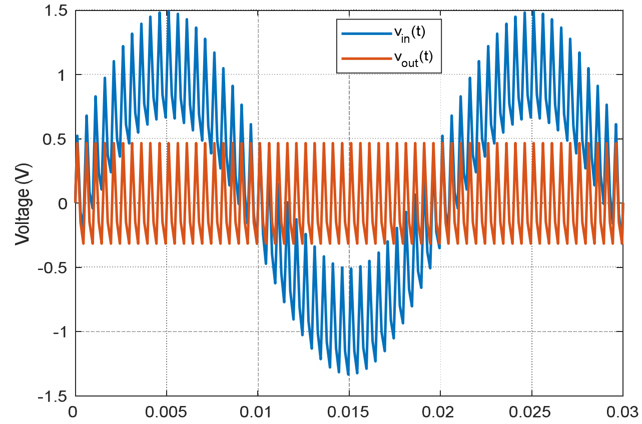

Fig. 7. 50-Hz free output voltage along with the input voltage.

To check whether the single-stage filter can eliminate harmonics of powerline frequency, we include the second- and third-harmonic junk in $v_{in}(t)$. $v_{in}(t)$ then takes the following form

$$v_{in}(t)=\underbrace{1\sin\left[(2\pi)50t\right]+0.3\sin\left[(2\pi)100t\right]+0.2\sin\left[(2\pi)150t\right]}_{\text{signals to be stopped}}+\underbrace{0.5\sin\left[(2\pi)2000t\right]}_{\text{signal to be passed}} \quad (11)$$

As can be observed from Fig. 8, although a single notch filter can eliminate 50-Hz interference efficiently, it finds it difficult to remove 100-Hz (second harmonics) and 150-Hz (third harmonics). The author suggests that these harmonics can be eliminated by cascading two more notch filters in series. The circuit diagram where three notch filters are connected in series to remove 50-Hz, 100-Hz, and 150-Hz hums, is shown in Fig. 9. For the case of notching 100 Hz and 150 Hz, we take the same capacitor of a value of 22 µF as in the 50 Hz case. Correspondingly, the values of inductors are calculated to be 0.2533 H and 0.1126 H, respectively. It can be seen from Fig. 10 that the cascaded notch filter successfully filters out harmonics of the power frequency.

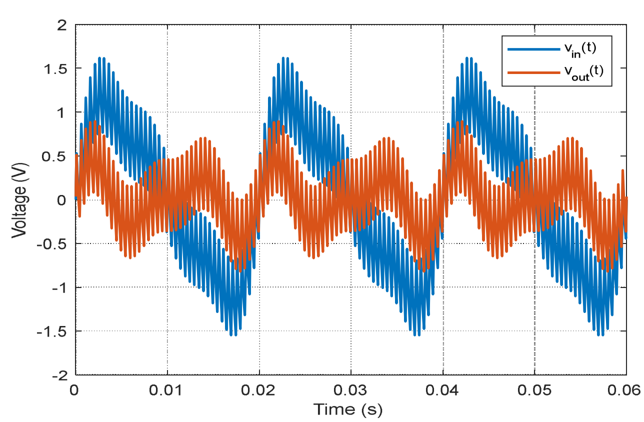

Fig. 8. Distorted output voltage along with input voltage.

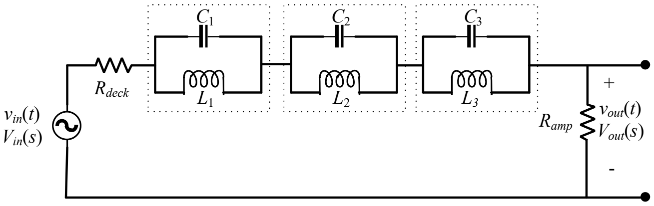

Fig. 9. Three notch filters are connected in series to remove 50-Hz, 100-Hz, and 150-Hz hums.

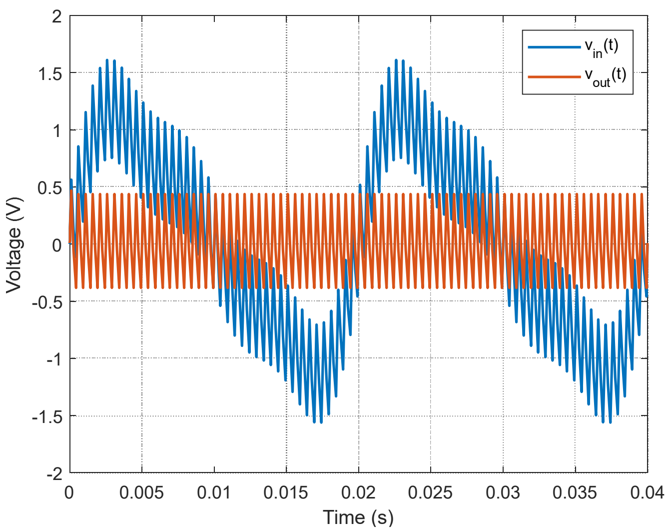

Fig. 10. Harmonics free output voltage along with the input voltage.

IV. Conclusion

In this paper, unwanted signals in the form of powerline frequency, i.e., 50-Hz, or its second or third harmonics that get interfered with the telephone transmission system and deck system, are removed with the help of a notch filter. It reinforces the established fact that notch filter can easily notch the unwanted frequencies. To notch second and third harmonics of power frequency, a cascaded notch filter may have to be used. The paper may come for the rescue of engineering students who intend to understand the basics of analog notch filters. The development of hardware for the considered systems can be carried out in the future.

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Design Layout and Installation Methodology of Cable Trays in a Distribution Substation of Pakistan

Umer Saleem, Muhammad Nasir Khan, and Ghulam Abbas

Department of Electrical Engineering, The University of Lahore, Lahore, 54000, Pakistan

Corresponding author: Umer Saleem (e-mail: umersaleem3218@gmail.com)

Abstract—**The purpose of our research work is to provide a design layout, installation method, and protection system for cables and wires through cable tray and ladder supporting systems in electric power generating, transmitting and distribution stations. This system provides different methods of laying cables on cable trays and supporting channels, which make it easy for cables to run between different electrical equipment and provide physical protection to the cables. The main objective of the proposed research work is to minimize premature cable failures and their consequences. It is found that the majority of cable failures in a substation are the result of poor layout of cable termination and mechanical damage during cable installation. Cable characteristics should be emphasized to the serious detriment. To achieve a sound cable system, it is necessary to provide good design, construction and installation as well as balanced characteristics of cables. The possibilities of electrical failure can be reduced by implementing the proposed method. The developed research work provides guidance for cable termination, cable routing and cable installation in substation as well as for commercial applications.**

Index Terms—**Cable tray, power transformer, substation.**

I. INTRODUCTION

It is found that the majority of cable failures in a substation are the result of poor layout of cable termination and mechanical damage during cable installation. It will also help the substation engineer to understand the universal practices for the installation of specific cables required in the particular areas of the substation to achieve better cable performance. To achieve a sound cable system, it is necessary to provide good practices of design, construction and installation as well as balanced characteristics of cables [1]-[2]. The authors in [3] emphasize in electrical safety and reliable operation of the substation. The possibilities of electrical failure can be reduced by implementing practices mention in [4]. There is more specific information involved in the installation of cable tray systems, on which this research work is done with design layout. The proposed work provides guidance for cable termination, cable routing and good installation practices of a cable system in a substation, which can also utilize in commercial applications [5]. For over many years, the use of ladder-type trays for support of cables has grown dramatically. Accompanying this increase is the need of large and longer cables to be installed. Designers and installers are continually facing many difficult challenges in the design layout and installation of cables in trays as per consumer demands [6]. With the increasing number and sizes of cables being installed, the existing raceways are becoming more heavily loaded. With such growth in the use of the tray, it is increasingly important that the trays and ladders should be installed as per the latest approved standards and specifications. It is important to consider a future provision in the initial design stages of cable trays to avoid overloading and breakdown of a cable support network.

Cable laying in a tray system requires many of the same considerations as required for installation in the conduit system [7]. Accurately, calculated data and adherence to the design limits of the cables being installed in trays with respect to tensions, weight and minimum required bending radii expands the feasibility for a successful installation and operation. Outrage occurs more frequently because of poor design and mishandling during installation or substandard protection after installation. Cable tray layout must take into deliberation of design limit of the cable [8]. With the more use of cable trays as a supporting system for electrical substations in Pakistan, it is beneficial that the electrical power sector accredits a uniform guide to be used as a standard for future development of cable tray system in Pakistan. Personnel unfamiliar with tray system could also use this material as a design aid. Cable trays, as mentioned here, are used as the standard support system for cables including high voltage, low voltage, control and communication cables [9]-[10].

As load demand increases in Karachi, Pakistan. Karachi Electric (K.E) proposed a scheme to enhance its electricity power by adding some new substations with extensions in existing substations in their electricity supply network. For this purpose, the project was started in 2016 named "TP-1000" rewarded to Siemens. This project involves a total 25 substations having voltage level 220 kV and 132 kV. Siemens decided to outsource the electrical work including the design of cable trays and supports of 10 major and important substations.

The proper installation of electrical cables plays an important role in the performance of substations. Poor arrangement of cable system causes many problems like damaging of cables, less maintenance space remaining, interference between power and control cables, cause difficulties for future cables that lead to existing system weakening. Previously, in most substations, cables are installed in bare conditions or conduits. Cable tray systems overcome large numbers of problems occurring in substations, therefore, cable trays are far more superior to the conduit system.

Previously, no proper cable trays/supports design was implemented which lead to a breakdown of cable trays and supports due to overload and wrongly routed of cables because there was no future provision considered. Therefore, there are two targets of my research work, one is to design the layout of cable trays and supports for substations for present work according to standard specifications and the second is to develop a universal guide for others. We have proposed complete design criteria for the installation of cable trays and supports by using proper international standards in this document.

II. The Proposed Strategy

This section includes different techniques of installation methods of various types of cable trays, cable ladders, and cable support on different areas of substation depending upon the location, trench size and power ratings.

A. Substation

A substation is a part of an electrical generation, transmission, and distribution system. Substations transform voltage from high to low or the reverse or perform any of several other important functions. Between the generating stations and consumer, electric power may flow through several substations at different voltages levels. All areas of substations are discussed in the following subsections.

B. Power Transformer

The dimensions of the power transformer's low voltage (LV) cable tray will be 100×300 mm (depth into width). This will be a floor-mounted cable tray supported by the double channel post base. LV cable tray will be mounted on the oil pit area below the grating of the Transformer and will connect to the control cabinet through the vertical cable ladder as in Fig. 1.

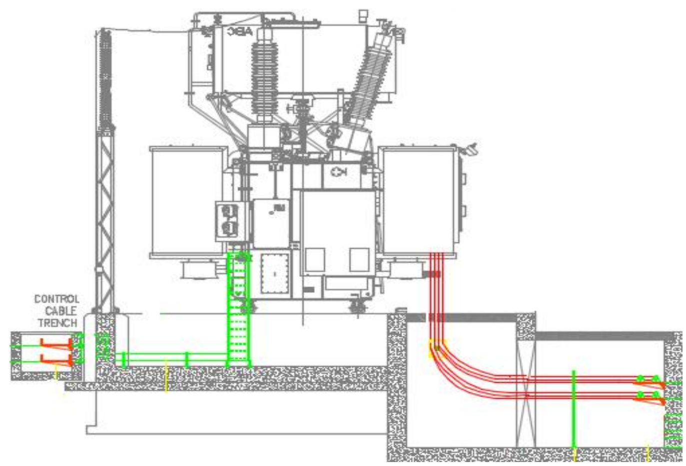

FIGURE 1. Power transformer's connection.

The other end of the cable tray will connect to the sleeves, which will further connect to the control cable trench. The distance between two double-channel post bases should be 1000 mm. On the LV side of the transformer, 12 number of cables in 4 trefoils will run on two wall-mounted hangers. Distance between two horizontally installed wall-mounted hangers should be 1000 mm. Clearance between two vertically installed wall-mounted hangers should not be less than 300 mm. The installation height of these hangers will depend on the actual site conditions.

C. 11 kV Switchgear Room

In this area LV control cable trays will hang from the roof above the 11kV panels. The network of the LV control cable trays will cover the whole MV switchgear room. Hanging cable tray should be aligned with the backside of the panel to avoid 11 kV Busbar installed in the middle of the panel. The distance between two consecutive hangers must be equal to 1000 mm. Separate cable trays should be used for LV control of 600 mm, LV power of 300 mm and LV SCADA cables of 300 mm. Wall-mounted hangers will be used to support MV cable. Clearance between the lower end of the hanging cable tray and the top end of the panels should be equal to 250 mm [11]-[13]. Clearance between two cable trays must be equal to 300 mm. To terminate MV cables from hangers to the bottom of the panel, double channel post bases will be used to support MV cables. Level of crossing cables should keep low so it can provide easy maintenance. All cables will be carried from ground floor to first floor through separate vertical cable trays. The length of the hanging rod can exceed up to 3000 mm.

Cable tray for SCADA cables should be of perforated type. Cable trays for power and SCADA cables should be connected from one side of the hanging rod only so control cables can easily approach the top cable tray for control cable tray as in Fig. 2.

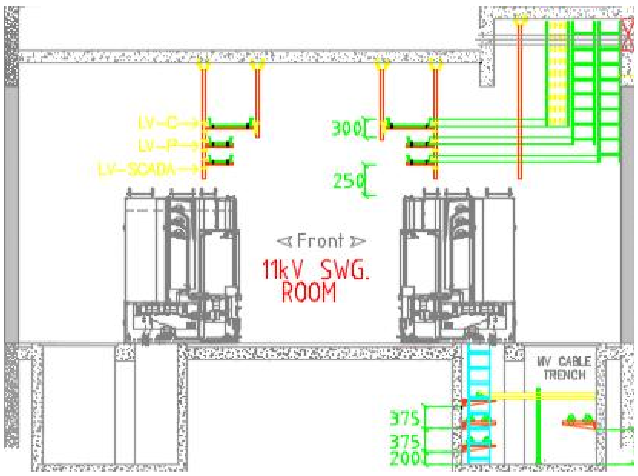

FIGURE 2. 11 kV switchgear room.

D. Line Control Cabinet (LCC)

LCCs are located inside the 132 kV & 220 kV GIS hall. Cable trays for power and control cables will install in the basement under the GIS hall. Several control cable trays depend on the number of panels. Commonly the number of cable trays is equal to the number of panels in GIS building with one extra cable tray for power cables. Control cable tray under GIS equipment is usually of 300 mm single layer. These cable trays will be supported by wall-mounted hangers as shown in Fig. 3 which will 1000 mm apart. The clearance between two vertical cable trays should be 300 mm. The size of cable tray will depend on the number of cables and the size of the trench. It could be off 600 mm or 450 mm.

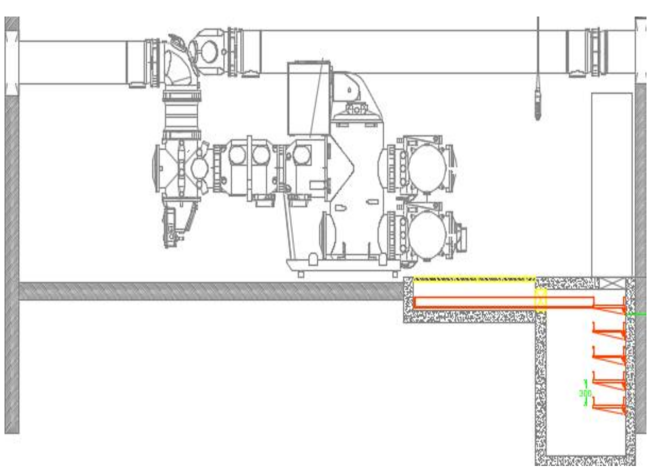

FIGURE 3. Line control cabinet.

E. Capacitor Bank

Normally, a trench of 300 mm is attached with the capacitor bank for control cables and a trench of 600 mm or 500 mm for 11 kV cable. A wall-mounted cable tray of 150 mm will install in the control cable trench. Wall-mounted hangers will install for MV cable coming from the outgoing capacitor panel inside the 11-kV switchgear room. Distances between two hangers either for cable tray or for MV cable should be 1000 mm. Vertical cable ladder will use to lift the MV cable from hangers to the terminals of the capacitor bank as in Fig. 4.

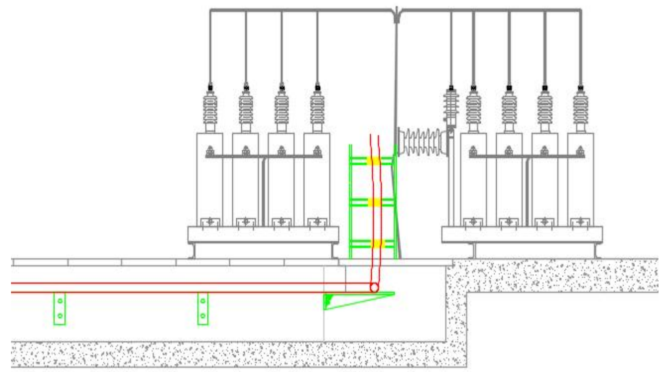

FIGURE 4. Capacitor bank.

F. Auxiliary Transformer

The auxiliary transformer also has two trenches. One is for LV cables and the other is for 11 kV cables. Due to a smaller number of control cables associated with the auxiliary transformer, wall mounted cable tray of 300 mm will be enough. The direction and length of the control cable tray will depend on the actual site conditions. Distance between two wall-mounted hangers should be 1000 mm. Both wall-mounted hangers or double channel post base support can use to support MV cable, as in Fig. 5.

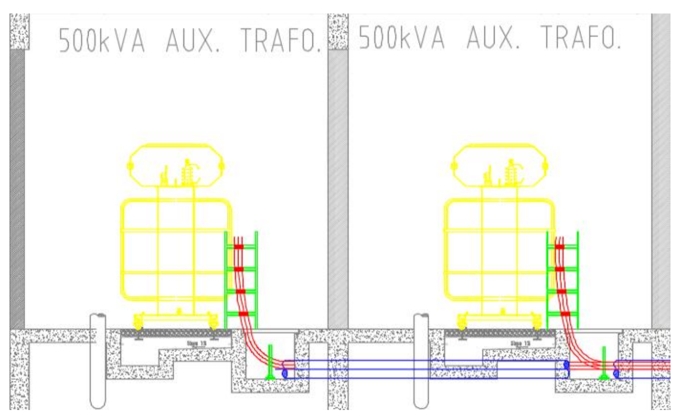

FIGURE 5. Auxiliary transformer.

G. Raised Floor

These are provided under the control house building floors of the substation below the panels. A raised floor is a type of basement of a room. It is constructing under the control room, AC/DC room, SCADA room, telecom room and battery room. Its floor consists of a 600×600 mm sheet network that spread across the whole room. To understand its foundations, a separate drawing of the raised floor is provided by the contractor. Cable trays of fixed 450 mm (single or double story) will install inside this raised floor on a double channel post bases by considering the foundations of the panels. The designing of cable trays on the raised floor may vary from engineer to engineer or depends on the required cable routing. Cable tray for SCADA cables must be of perforated type.

The structure should be 1000 mm. Proper insulation and separation should be provided between each HV cable to avoid interference. The height of the trefoil structure will depend on the actual site conditions. Proper maintenance space should separator must be installed if control and power cables are going to run in the same cable tray. The distance between two double-channel pose bases should be 1000 mm. Maintenance space should be considered while designing the cable tray network. Horizontal elbows and tees should be installed at their required place in the cable tray network. An example is shown in Fig. 6.

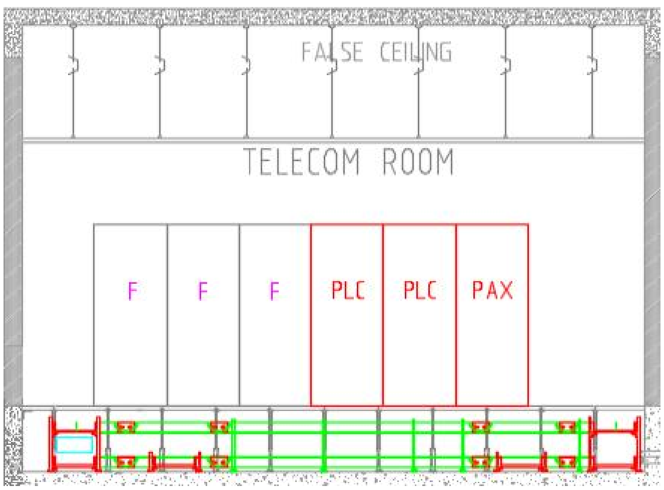

FIGURE 6. Horizontal elbow and tees.

The single or double-layer depends on the number of cables and weight on the cable tray. The height of the raised floor is 800 mm fixed. Minimum clearance between the raised floor and upper cable tray should be 200 mm and the distance between two cable trays should be 300 mm. While the minimum distance between two parallel cable trays should be 100 mm.

H. HV Cable Support

HV cables 132 kV & 220 kV will run on the floor-mounted HV support flat structure and wall-mounted trefoil arrangement structure. Distance between two HV flat supports should be 1000-1500 mm depending on the actual site conditions. HV cables will fix these structures with the help of clamps. Minimum clearance between two HV cables should be equal to the diameter of the cable. Similarly, at the crossing of two HV cables, minimum clearance between two cables should be equal to the diameter of the cable. The route and height of HV cable support flat structure depend on the actual site conditions and requirements. The bending radius of 1200 mm should be maintained for HV cable. Trefoil arrangement structure will use to support HV cables in less wide trenches. Distance between two wall-mounted trefoils is considered. Proper clearance between new and existing HV cables should be considered. An example is shown in Fig. 7.

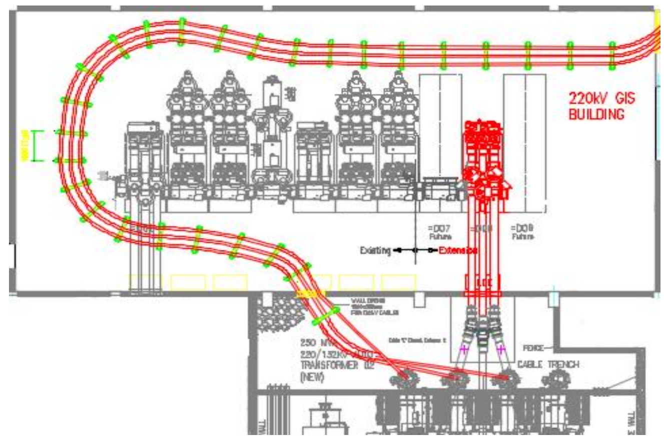

FIGURE 7. HV cable support.

I. MV Cable Support

Both wall-mounted hangers and floor mounted double-channel post base structures can support MV cables. The selection of one depends on the site conditions and requirements. Distance between two structures should equal to 1000 mm. Before entering the MV room, MV cable will run on the wall-mounted hangers within the trench. After entering the MV room, MV cable will run on floor-mounted structures under the panels, as shown in Fig. 8.

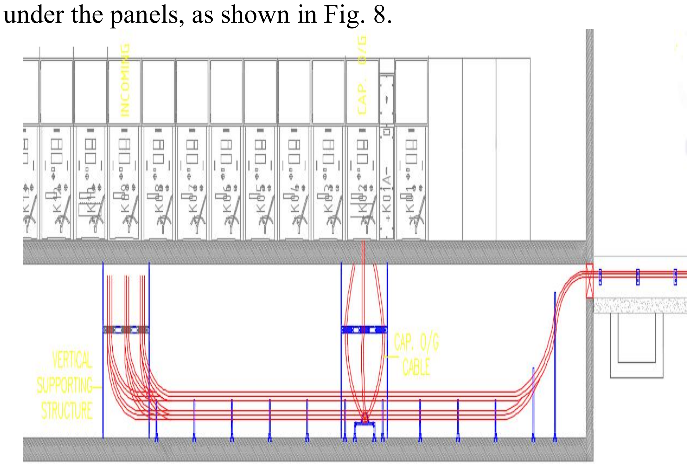

FIGURE 8. MV cable support.

Route of MV cable from PTR to MV panels may vary from engineer to engineer. The height of floor-mounted supports can be different in different areas of MV cable. Vertical cable ladder support will be used to lift MV cable from floor mounted support to bottom terminals of the panels maintaining the required bending radius. Clamps will also be used to tie MV cables at different supports.

J. Loading and Filling Calculations

These are prepared after receiving the cable schedule made by a protection engineer. One way to decide the size of the cable tray in a particular area depends on the number of cables associated with that area. After deciding the size of the cable tray, it should decide how many cables will be going to run through that cable tray. Calculations of cable loading and filling in cable trays are a very important factor for any substation. It ultimately affects the life of cable trays installed in a substation. So, one should follow the standards regarding these calculations.

K. Cable Filling Ratio

According to international standards, any cable tray should be almost 60% fill with cables. If the filling ratio exceeds 60%, another cable tray should be adding or the route of the remaining cables should be changed. This practice increases the life of the cable tray. Further, it also provides easy maintenance for cables and cable trays. Cable filling ratio can be calculated by dividing the total cross-sectional area of all cables by the total cross-sectional of cable tray, as shown in Table I.

TABLE I
CABLE FILLING RATIO

1. 11kV Room Control Cable Tray for (Incoming,Outgoing,Capacitor O/G, Transformer O/G & BUSCOUPLER Panels)					
Cable Size	Number of Cables	Cable Dia(D)	Radius (D/2)	Cross-Sectional Area	Total Cross-Sectional Area
sq.mm	No.	mm	mm	mm2	mm2
12x2.5	17	27.8	13.9	607	10318
4x2.5	35	21.4	10.7	360	12588
4x4	1	23.6	11.8	437	437
4x6	1	25	12.5	491	491
	Total				23835

Control Cable Size	=	600
Tray Loading Height	=	100
Cable Tray Cross-sectional Area	=	60000
Cable Tray Filling With(1 tray)	=	40 %

Hence One (01) no. Cable Trays of 600mm has been propsed with 40% fill ratio

L. Cable Loading Ratio

The quantity of cable installed in any tray may be limited by the structural capacity of the tray and its supports. Tray load capacity is defined as the allowable weight of wires and cables carried by the tray. According to international standards, the maximum loading of cables in any cable tray should be 150kg/m. Although the loading depth of any cable tray is 100 mm subtracting rung. Weight of cables after filling 60% of the cable tray with cables should be less than the maximum loading capacity. If we follow this standard, there will be no bending of the cable tray which increases the life of cable trays. As shown in Table II.

TABLE II
CABLE LOADING RATIO

1.11kV Room Control Cable Tray for (Incoming,Outgoing,Capacitor O/G, Transformer O/G & BUSCOUPLER Panels)					
Sr. No.	Cable Sizes	No. of Cables	Cable Weight	Total Weight	Remarks
	Sq.mm		kg/km	kg/m	
1	12x2.5	17	1036	17.612	
2	4x2.5	36	549	19.764	
3	4x4	1	699	0.699	
4	4x6	1	831	0.831	
	Total	**55**		**39**	

Total Numbers of Cables	=	55	
Total Weight of 55 Cables	=	39	kg/m
We use One Cable Tray so			
Max Capacity of **600mm** Cable Tray	=	149	Kg/m

Weight of Cables is Less then the Maximum Capacity of Cable Tray

149 kg/m > 39 kg/m

Hence Cable Tray Size is OK

M. Cable Routing

The general practice is to decide the shortest route of cable from point A to point B, which helps to control the wastage of cables and reduce the cost. Route of cables should also be decided by following the cable tray loading and filling calculations. Route of cables should be changed if the filling ratio reaches 60% or the loading ratio exceeds its limits within a cable tray. In hard cases, if there is not any other possible route, then the filling ratio could be increased up to 65%.

N. Cable Tagging or Identification

Cable tray sections should be permanently identified with the tray section number as required by the drawings or construction specifications [2]. Cable tags are marked to the cable trays, which show the designations of the cable. These tags help to understand the termination of cable from point A to B. The tags are given in cable schedule for each particular cable to understand the path of cables, as shown in Fig. 9. The way or design of cable tagging/mapping and nomenclature on a cable tray may vary from engineer to engineer.

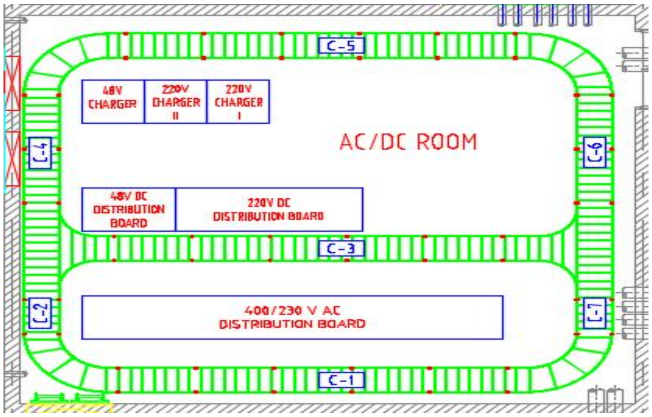

FIGURE 9. Cable tagging or identification.

O. Bill of Quantity

After getting approval of drawings, BOQ needs to be prepared. As cable trays are concerned, their BOQ includes total quantities of all the parts of cable trays, cable supports, their dimensions, their specifications, material information, etc. Always add a factor of 10 to 15 percent more than the original quantity of material. There is no problem if the value exceeds the required limit, but it should not be less as shown in Table III.

TABLE III
BILL OF QUANTITIES

DESCRIPTION	TYPE	UNIT	1	2	3
			OGL	GAD	LBS
Cable ladder (600MM WIDTH)	Type Hot Dipped Galvanized After Fabrication (HDGAF), length 3000mm Rung spacing 150mm, material thickness = 2mm, Loading depth=100mm	m	165	150	270
Cable ladder (450MM WIDTH)	Type HDGAF, length 3000mm Rung spacing 150mm, material thickness = 2mm, Loading depth=100mm	m	266	265	260
Cable ladder (300MM WIDTH)	Type HDGAF, length 3000mm Rung spacing 150mm, material thickness = 2mm, Loading depth=100mm	m	85	55	160
Cable ladder (150MM WIDTH)	Type HDGAF, length 3000mm Rung spacing 150mm, material thickness = 2mm, Loading depth=100mm	m	30	5	22

III. CONCLUSION

Due to economic reflection, the implementation of a cable tray system as an approach of cable lying is on the growth. With such growth, a guide is requiring to bring design personnel with basic information. This research is an effort to assemble enough basic information on cable trays and place them in a readily usable form. This methodology of designing cable trays and their supports by following the defined standards and specifications is the solution to many problems related to an electrical cable system. Damaging of cables will be reduced, less interference, better performance, and more maintenance space available, provision of future cables will be available. The practical results with or without implementing this methodology of designing cable trays and their supports will be compared in this study.

While installing more cable trays, it is of vital importance to know that installation guidelines/instructions should be consulted to ensure trouble-free and reliable service life. Optimal size, rating and location, and utilization of the equipment help in the successful installation of cable trays. The installation limits constraint of the cable to be installed should be met while designing a new cable tray. Most field installation problems can be avoided by proper pre-design.

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Preparation Optimal Economic Solution with UPFC, for a Large Size Industrial Plant

Muhammad Kashif Rasheed *[1], Muhammad Farooq Aslam [1] and Muhammad Kamran [2]

[1]Electrical Engineering Department, The University of Lahore, Lahore, 54000, Pakistan
[2]Electrical Engineering Department, UET KSK Campus, Lahore, 54000, Pakistan
*Corresponding author: Muhammad Kashif Rasheed (e-mail: Kashif_rasheed2012@yahoo.com)

Abstract- **The Flexible Alternating Current Transmission System (FACTS) devices have opened new doors for controlling the power flow over the transmission line and to enhance the usable capacity of an existing power system. Unified Power Flow Controller (UPFC) is a versatile device which can independently control the line voltage and active and reactive power flow on the transmission line. This research shows that a UPFC is able to control both the transmitted real power and, independently, the reactive power flows at the sending and the receiving end of the transmission line. The UPFC model is applied to an existing large size power plant, installed on a 132-kV transmission line. The main objectives are to control active and reactive power flow and to minimize the power losses thus improving the overall economics of the system. MATLAB/Simulink has been utilized for simulations. The results show a considerable saving in the operation of the plant.**

***Index Terms*— Active and Reactive Power flow, Transmission Network, Unified Power Flow Controller, Voltage Source Converter.**

I. INTRODUCTION

The world has paid great attention towards minimizing the cost of energy and to ensure quality of power with minimum inefficiency in electricity production, transmission and its distribution particularly for the industrial purposes. Cement production is a high energy consuming process in terms of electricity and thermal energy. Energy consumption by a typical Cement Plant is estimated about 30% of the total production cost. Electrical equipment installed in Cement industries is mainly consist of induction motors, industrial pumps, crushers, industrial fans and compressors. These equipment's consumes different amount of power and in different form for their smooth operations. The power we received from grid is in high voltage and same is distributed among the installed electrical equipment as medium or low voltage as per equipment requirement with the help of step-down Transformers installed at different sections of the Cement Plant. These large number of electrical devices and their power consumption makes a major cost factor for cement production. As, most of the Cement Plant load consist of motors and Transformers and these loads are inductive in nature and their presence make the network overloaded and thus result in voltage instability due to imbalance of the reactive power in the network and lower values of power factor [1].

Low power factor not only overload the electrical network but also make the installed equipment inefficient with an increase in the rating of Transformers, switchgears and cable cross sectional areas to meet the same load demands with an additional increase in cable losses and line current drawn by the network. To overcome these issues of Power Factor and voltage stability different FACTS devices are being used [2]. Most promising device known as UPFC because of its capability to provide excellent power flow control, voltage stability and voltage regulation. UPFC can work as STATCOM or SSSC when the DC link switch between two voltage source converters of the UPFC is open and work as UPFC when the switch of the DC link is closed [5].

The research investigates the suitability of a UPFC for decreasing the power loss as well as alleviating the problems of voltage instability. The technical and economic benefits obtained by power factor improvement are discussed in detail. A simulation model was developed in Simulink for a real existing cement plant of about 32 MW size.

II. PRINCIPLES OF UNIFIED POWER FLOW

A. OPERATING PRINCIPAL OF UPFC

Dr. L. Gyugyi proposed the UPFC in 1991 [1], [2]. Unified Power Flo Controller having two voltage source converters which are linked through a common DC link via a switch.one converter is connected in series with the line through a transformer. Second converter is connected in shunt with the line with another transformer. The schematic is shown in the Fig. 1. If the DC common link switch is open it acts as STATCOM or SSSC. If the switch is closed it acts as UPFC.UPFC has unique characteristics to control the all line parameters. The Active and Reactive power can also be controlled. The control of Active power is without changing the reactive power. The Series converter can control the reactive power by injecting a voltage in series with the line which is in quadrature to the line current.

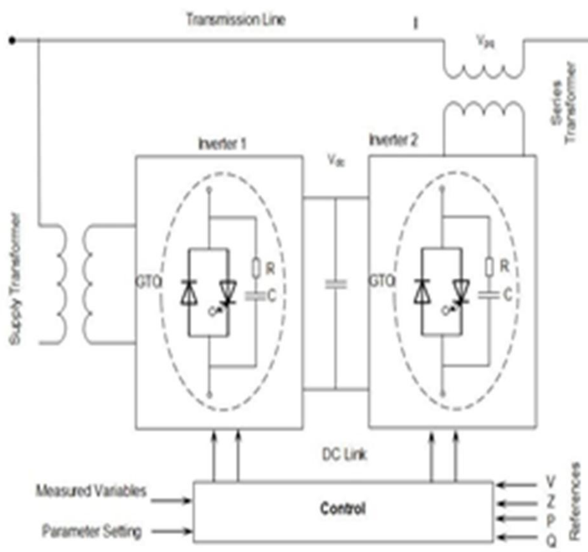

FIGURE 1. UPFC schematic.

Whereas the active power is controlled by the series converter by injecting a voltage in line which is in phase with the line current. The main function of the shunt converter is to supply/absorb the active power demand by the series converter which appears on the DC common bus. Shunt converter can also control the reactive power [8]. The Active and Reactive Power relations are described in equation 1 and 2.

$$P = \frac{VsVr}{X} Sin\alpha \quad (1)$$

$$Q = \frac{Vs(Vs - Vr)}{X} Cos\alpha \quad (2)$$

It is clear from the above relation that active power is dependent on the power angle whereas reactive power is dependent on the difference of the voltages of sending end and receiving end. In order to control the voltage regulation and active power flow the UPFC series converter will inject a voltage of any magnitude and desired phase angle to control the flow of power on the transmission line where as the shunt converter will regulate the bus voltage to which it is connected.

B. UPFC CONTROL SCHEMES

UPFC can act as STATCOM and SSSC if the DC common link switch is open. The control schemes of both STATCOM and SSC are explained below [9].

a) SERIES CONVERTER

The mode of operation of the series converter is in automatic power flow and the injected voltage by the series converter is determined by the closed loop control for desired power. The reference values of the active and reactive power (P_{ref}, Q_{ref}) are compared d with the P_m and Q_m of the line. The difference of these values as error send to the PI Controller for the generation of V_d and V_q. The below equations can be used for the calculation of magnitude of V_{pq} and α [11].

$$V_{pq} = \sqrt{(V_d^2 + V_q^2} \quad (3)$$

$$\alpha = tan^{-1}\left(\frac{V_q}{V_d}\right) \quad (4)$$

With these values of Vdq and α Space Vector Pulse Width Modulation (SV-PWM) pulse generator generates pulses for Series Converter to ensure desire power flow in the line. Series Converter control is shown in Fig. 2.

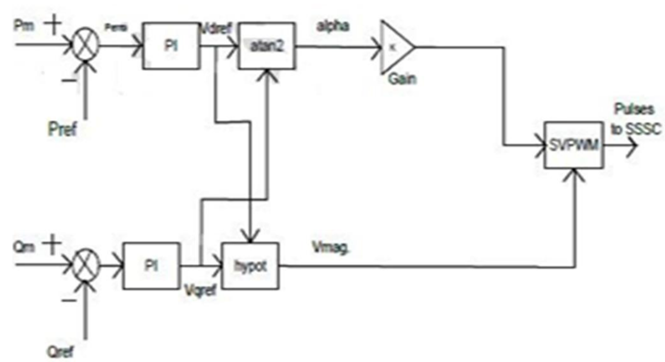

FIGURE 2. Series converter control.

b) SHUNT CONVERTER

The mode of operation of the shunt converter is Voltage Regulation. The control strategy is shown in Fig. 3. This control scheme is used for directing the reactive power absorb/generate by Voltage source converter. The phase locked loop (PLL) provide the reference angle. The real Id and reactive Iq parts of the current are calculated. The value of Vd is compare with the reference value of the shunt voltage Vshref. PI Controller received the error and it generate the reactive component of current Iqref [12]. The real part of Idref is calculated by comparing the voltage Vdref and DC Capacitor voltage Vdcm. The measured values of real and reactive components of currents are compare and the error is sent to PI Controller for the generation of Vd and Vq. Moreover, Vdq and are calculated by equation 2 and 3. With these values of Vpq and α Space Vector Pulse Width Modulation (SV-PWM) pulse generator generates pulses for Shunt Converter to ensure voltage regulation [13].

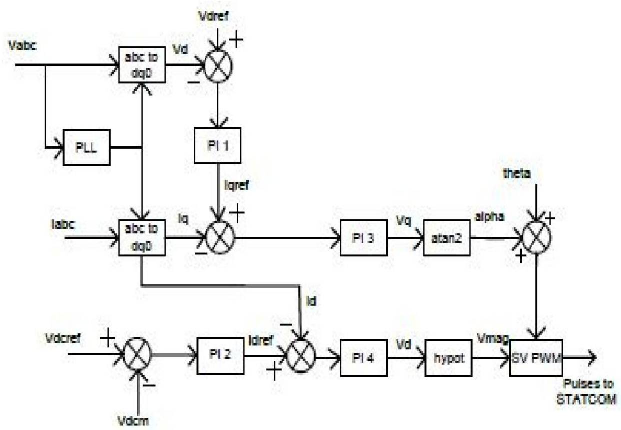

FIGURE 3. Shunt converter control.

III. TEST SYSTEM

DG Cement Plant is governed by 132 kV grid transmission lines and its power consumption is nearly 30 MW. Three sections of Plant have more distortion in the power system are, Kiln section having a total load 9600 kW, Raw Mill section having a load of 9400 kW and Cement Mill section which has a total of 2500 kW. As, most of the equipment installed in the Cement plant is consist of motors, Transformer which are inductive load in nature. These loads absorb the additional inductive reactive currents and consequence of these currents is such that it makes the system inefficient and result in low power factor of the system.

Furthermore, these inductive loads in the DG Cement Plant is an important component of the total system load that contributes to the Voltage instability. These are fast restoring loads (in the time frame of seconds) and requires high reactive powers. Due to the reactive power requirements by these loads and its presence at the end of the lines an imbalance is created in the system which is a major reason of voltage stability issue in the DG Cement plant.

TABLE I
LOAD DETAILS OF THE PLANT

Section	Total Load
Kiln	9600 kW
Raw Mill	9400 kW
Cement Mill 1	5250 kW
Cement Mill 2	5750 kW
Miscellaneous Load	2000 kW
Total Load	32 MW

A. MATLAB/SIMULINK MODEL

The UPFC is used to control the active and reactive power flow over the 132-kV transmission line. The Cement Plant under this study, is connected in a loop configuration and consist of five buses (B1-B5) which are interconnected with each other through three transmission lines TL1, TL2 and TL3 as shown in Fig. 4. A step-down Transformer of 34 MVA is connected between B4 and B5.

UPFC installed with the system will control the active and reactive power flow control with the help of the series converter by injecting a voltage of desire magnitude and phase angle to maintain the desire power flow over the line. The voltage regulation is achieved through shunt converter to overcome the issue of voltage instability of the system. The rating of the Series Converter is 1MVA and maximum injection is 10% of the nominal line to ground voltage in series by this converter. The DC Capacitor link value is set to 750 µF and DC link nominal voltage are set to 40kV.The Series Converter is set to operate in Power Flow Control Mode. The rating of the Shunt Converter is 1MVA and the rate of change of reference voltage is set to 0.1pu. The Shunt Converter is set to operate in Voltage Regulation Mode.

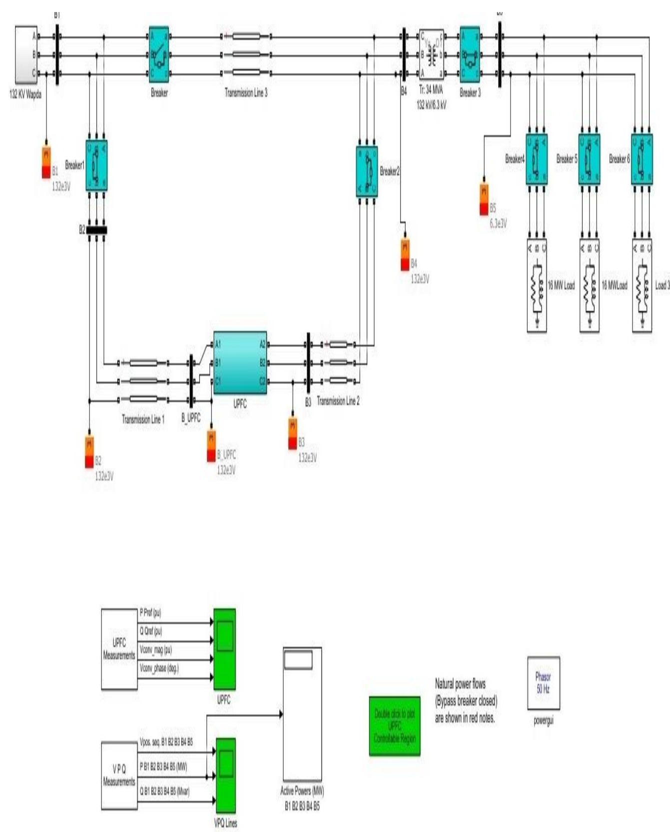

FIGURE 4. MATLAB /Simulink model of DG cement plant.

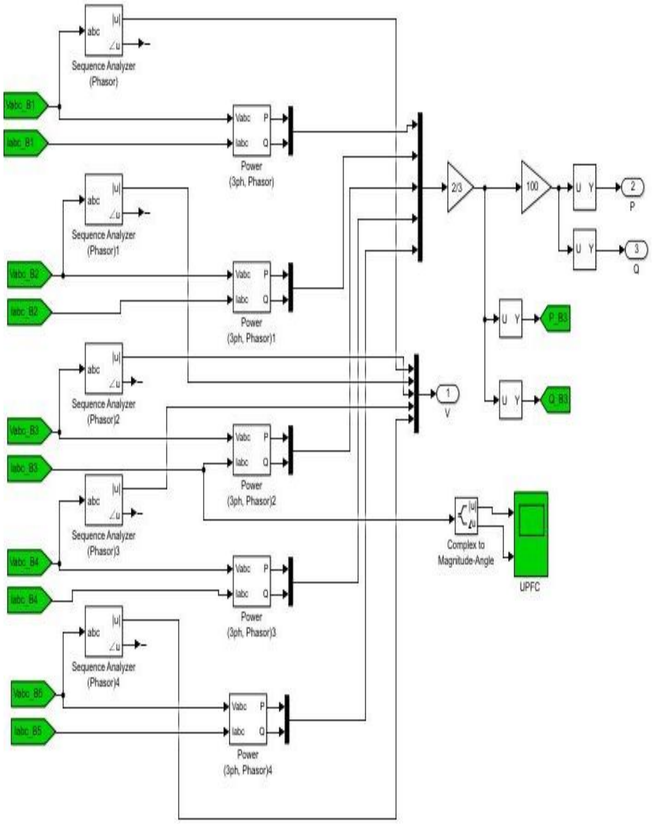

FIGURE 5. P and Q measurement block.

IV. SIMULATION RESULTS

The behavior of the plant is observed for 20 seconds. From 0 -10 sec power system is run in normal condition and UPFC is remain in bypass mode and after 10 sec UPFC model synchronizes with the system and start its working. The results are shown in Fig. 7.

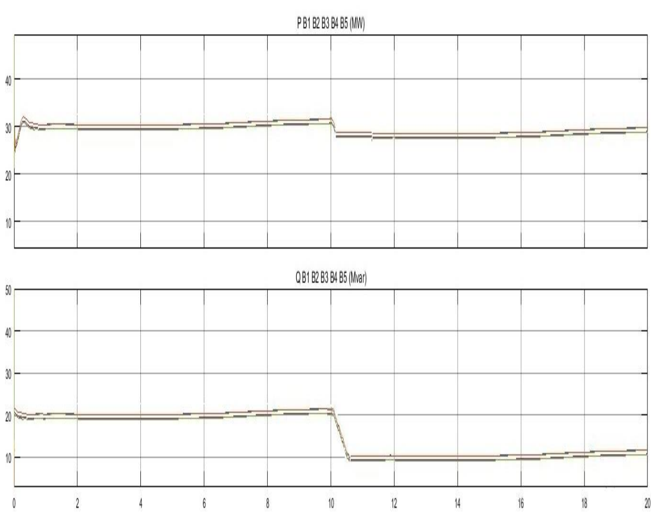

FIGURE 6. P and Q simulation results.

TABLE II
VOLATGE, P AND Q WITH AND WITHOUT UPFC

Bus No.	Bus Voltage without UPFC	Bus Voltage with UPFC	Bus Power without UPFC		Bus Power with UPFC	
	Voltage (Pu)	Voltage (pu)	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)
1	0.9966	0.9967	30	19.37	28.65	10.40
2	0.9993	1.0020	29.9	19.32	28.55	10.35
3	0.9996	1.0010	29.8	19.26	28.45	10.30
4	0.9926	0.9942	29.7	19.19	28.35	10.29
5	0.9978	0.9978	29.6	19.12	28.25	10.24

From the simulation results as shown in the tables it can be evaluated that that the power factor corrected from 0.84 to 0.94. Furthermore, the reactive power is reduced by 46% and apparent power is reduced by 14%. The value of Active Power reduced is due to the decrease in power losses which are due to power factor improvement of the system.

The reduction in value of reactive value also benefits in terms of less rating of cables, transformers, switchgears and other equipment. Furthermore, the imbalance of the reactive power in the system is improved which results in voltage stability of the system.

The response of voltage variation after using the UPFC. The simulation results show that a voltage of 0.1 pu is injected at an angle of 135 degrees to improve the power factor from 0.84 to 0.94 to meet the acceptable range of WAPDA/NTDC.

V. ELETRICITY SAVINGS

UPFC device has been placed in the power system of DG cement plant. Overall desirable results have been achieved. It is important to carry out the cost benefit analysis to ensure its feasibility in the Cement Plant to get maximum benefits in terms of cost saving. It is important to know here that other total load of this plant for WAPDA is considered to be approximately 30 MW. Keeping in view the electricity consumption of the plant from IESCO (Grid) from 2017- 2018, details are given below:

Power Consumption without UPFC = 30 MW
Total Power Consumed using UPFC = 28.65 MW
Total Power Saved = 1.35 MW
Total Amount of Energy saved per annum = (Power saved) x (hours/day) x (days/ year)
= 1.35 MW x 24 x 365
= 11,826,000 kWh
Flat Rate = 20 Rs/ kWh (Average cost per unit)
Total Amount saved (Rs) = (energy saved/year) x (flat rate)
= 11,826,000 x 20
= **236,520,000 PKR**

VI. BREAKEVEN PERIOD

Cost of Series and Shunt Controller for UPFC = $300/kVar
Total Power Saved by installing UPFC = 10 MVar
Cost of Controllers on DG Cement Plant = 300 x 10,000 kVar
= $ 3,000,000
Conversion of USD to PKR: $1 = 155 Rs.
Cost of UPFC in PKR = 3,000,000x 155
= **465,000,000 PKR**.

The cost of controllers is high initially. However, in 2 years, the power consumption can be done to the point that the industry can payback the cost of the controller. The installation and maintenance charges will approximately lead to a breakeven period of 4-5 years.

VII. CONCLUSIONS

UPFC device simulated on electrical system has shown quite good result for suitability as an optimal solution for large industrial plants to ensure voltage stability, reduction in power losses and improvement in the overall power factor of the system for efficient operations of the plant.

The series converter is in automatic power flow mode and shunt converter in voltage regulation mode is simulated. The results shown that fast response and effectiveness of UPFC in controlling active and reactive power flow and voltage regulation of the transmission line to which UPFC is connected with the help of PI Controller based control scheme.

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Experimental Analysis and Cost Comparison of Evacuated-Tube Solar Water Geyser with Flatbed Solar Water Geyser Fabricated as per Local Conditions of Pakistan

Umer Akram, Ahmed Nazar, Muhammad Imran, Nadeem Ahmed, Hafiz Muhammad Zubair

[1]Mechanical Engineering Department, The University of Lahore, 1-KM Thokar Niaz baig, Raiwind Road, Lahore, Pakistan
*Corresponding author: Umer Akram (email: umer.akram@me.uol.edu.pk)

Abstract—**Surging demand for energy and the current energy crisis in the world has forced initiatives to look for alternative and cheaper energy sources and one of them is solar energy. The motivation is to provide a clean pollution free source of energy which is environmentally friendly, renewable and cheaper. A large population around the globe uses open fire for water heating, thus solar water geyser has economic and environmental benefits as well. This study is aimed to explore the possibility of designing and fabricating cheap SWHs, calculating their performance through experimentation and estimating the costs involved, so that cheaper SWHs can be used in developing countries like Pakistan. Once such renewable solutions are available to meet energy demands, it can greatly help lower the consumption of fuels and hence uplifting economy for the betterment.**

Index Terms— Solar Water Heaters, Performance Calculation, Renewable Energy, Design and Fabrication.

I. Introduction

A solar heater (or geyser) uses energy from the sunlight for heating water in winters. Solar heaters are easily available in the market most of them are relatively in expensive and low technology, while others are expensive and advanced. As solar water heaters require no fuel, many organizations are thus promoting its use in less developed countries for saving fuel and avoiding environmental pollution. Solar heating is used in situations where fuel or electricity consumption has to be reduced or in places where chances of accidental fires are very likely or the health and environmental consequences of alternative form of heat generation to heat up the water are severe. With the increase in the prices of electricity and fuel there is a demand for cheaper source of energy. Solar energy has thus become a viable option. Solar heater has begun to be used widely in a number of developed and under developed countries and especially in remote areas where fuel or electricity is scarce.

Flatbed solar water geyser consist of silver tube, Wooden frame, silver sheet, Glass cover and storage tank for later use. Water tank is insulated with glass wool to reduce the loses of heat energy losses. No requirement of fuel not only reduces cost but also protects the environment from damages caused by fuel use. These heaters can heat up water in a few hours depending upon the availability of sunlight and the design of the heater. Most importantly people don't have to walk for miles just to get the fuel that they require. Using a solar geyser, they just have to go outside and use the heat given by the sun for free. It is estimated that using a solar heater for a year can eliminate the need for 1 ton of firewood.

Solar heater also helps reduce environmental pollution. Burning wood releases smoke filled with particulates that are not only bad for the environment but also harmful for the people who are breathing it. These particulates produced by open fires can cause health problems including lung and heart diseases. According to an estimate 1.5 million people die every year from this type of air pollution. A solar heater eliminates the need for an open fire thus reducing the danger of air pollution.

In countries like Pakistan facing the energy crises due to shortage of liquid and gaseous fuels, in such cases the demand of solar energy techniques is increasing rapidly. The solar energy is environmentally friendly. The solar energy has no cost, sales tax and shortages. Due to which it is a permanent source of energy. This study is aimed to introduce cheap SWHs fabricated and then tested through experimentation and compared with available commercial product in Pakistan. Fabrication materials are available and can easily be accessed in Pakistan, and the design is validated by performing necessary calculations.

II. Working Principle

A Solar water geyser takes in the stream of cold water through an inlet pipe which leads it to steel tank that is actually a heat exchanger. Cold water stream then flows the solar collector where solar energy is harnessed and water becomes hot by taking this heat of sunlight. Hot water again passes through the heat exchanger tank in a counter flow fashion so that the heat transfer can take place effectively between the two streams of water. This helps is more efficient heat transfer. Hot water is then delivered or utilized for specific purposes as per requirement. A diagram that depicts the working of solar water heater is shown below (figure 1).

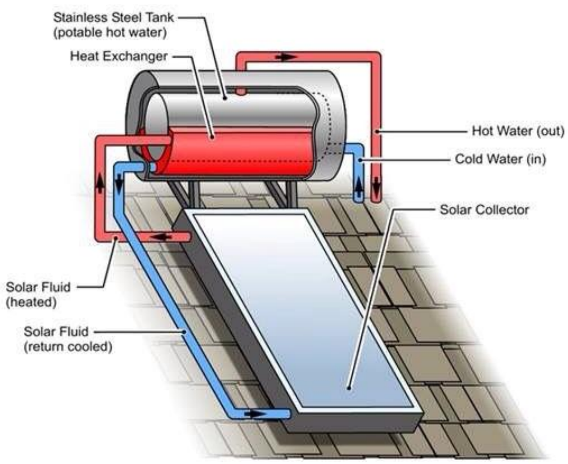

Figure 1. Working principle of solar water heater.

III. Literature Review

Since 1980, solar energy's global use has increased up to 30% [1]. RE Policy Network reported in 2010 that approximately 70 million homes are using Solar Water Heaters in the world [2]. SWH originated in 1767 when Swiss naturalist DeSaussure made an insulated painted black box that was covered from the top by two glass panes [6]. The first SWH on commercial level was named as climax and was built by Clarence Kemp in 1891[7]. In Pasadena, California a large number of residential buildings installed SWHs by the year 1897[8]. William Bailey introduced Thermosiphon effect for the very first time and defined circulation paths of water and steam [9]. Until 1930, coal fired boilers were commonly used all over the world for space and water heating [10]. SWH was considered as a commercial product in 1960s. In 1927, T.G.N.Haldane introduced HP technology for the first time. Despite of very high efficiencies, HP technology is expensive and hence cannot be used in places where cost becomes as limitation.

SWHs are not complex machines, having simpler designs having a variety of benefits. Assessment of resources, appropriateness of the technology and cost estimation contribute towards evaluating such project. There have been various studies conducted regarding the science of collectors' location and size, and how the heat can be transferred efficiently [11]. Water is most commonly available fluid with properties that are often taken as standard values at room temperature conditions.

In cold climate, the choice of fluids can vary. Similar is the case for hot climates, high boiling fluids are required there. Pumping required for any specific case is determined by fluid properties such as viscosity and freezing/boiling points. Other properties also help for estimating the appropriateness of a fluid such as stability and corrosiveness. On large scale the electrical backups are required which tend to lower the energy savings. However, it is still difficult to understand the piping systems for SWH in underdeveloped countries as there are specific standards for all areas [12].

The synchronization of solar collector with sun's motion has shown an increased thermal efficiency [13]. Solar Water Heaters that work on Thermosiphon effect eliminate the need of pump and hence a better option. Collector efficiency can be improved by the use of fins over the external surface of collector [14]. If the overall performance of a Solar Heater can be improved, it can help bring down the costs [15].

In 2019, Esdras Nshimyumuremyi and Wang Junqi [16] designed a solar water heater in Rwanda for the analysis of thermal efficiency and performance. Similar work has also been done in India in 2014 by P. Veeraboina [17] where solar factors and different performance indicators have been analyzed for a designed Solar Water Heater. This study is based on the extract of these two recent works and our system has been analyzed accordingly.

IV. Methodology

SWHs are usually responsive to solar irradiance intensity I and ambient temperature (outside air). In cold climates, at nighttime, inside space and all parts of solar water heater are cooled up to the ambient negative temperature tout. In the morning, after sunrise, there is a rise in solar intensity and hence temperature of outside air rises. As a result, solar radiation penetrates into solar water heater and absorber sheet absorbs it, which causes a growing of the temperature in the inside space of solar water heater. For exact calculations of SWHs performance, solar intensity and ambient temperature of air must be taken into account.

For the purpose of experimentation, a commercial Evacuated-tube SWH has been selected (shown in figure 2) for performance analysis. Then using cost analysis, an alternative cheap SWH (Flatbed SWH) has been designed using

SOLIDWORKS software and later fabricated as shown in figure 3. Mathematical calculations are performed for both the machines to see whether fabricated product matches in performance with the commercial product.

Figure 2. Fabricated flatbed solar water heater using cheap materials.

Figure 3. Fabricated flatbed solar water heater using cheap materials.

Efficiency is the ability to avoid any possible heat losses. The lesser amount of heat losses means more input can be converted into useful output.

Efficiency, η = Heat Energy Output/Heat Energy Input

Efficiency, $\eta = Q_{out}/Q_{in}$

Solar Energy Fraction (SEF) is ratio in energy terms between the useful output that machine has produced and the required input. There can be various forms of energy inputs and outputs such as electrical, chemical or thermal etc.

$$SEF = \frac{Q_{del}}{Q_{Aux} + Q_{part}}$$

Q_{del} - Energy that is delivered to water.

Q_{Aux} – Heat consumed by any auxiliary element on daily basis.

Q_{par} – parasitic energy means the electrical energy in AC form that is used to run various components.

Solar Fraction (SF) is the net amount of energy that is provided by using solar technology to the machine. It is an important performance indicator and can be calculated by using the mathematical relation;

$$SF = 1 - \frac{EF}{SEF}$$

The EF for standard auxiliary tank is taken as 0.9. Calculations for both systems (flatbed solar water geyser & evacuated tube solar water geyser) have been performed. Different methodologies for calculations of performance of both systems are used to determine which system is more efficient.

Experiments were on the evacuated tube solar water geyser to study temperatures that it achieves during different days. The experimental tests on solar water geyser were carried out different days from 11 March 2019 till 11 April 2019. Each experiment starts from 08:00am-10:00am, 12:00pm-02:00pm and 05:00pm-07:00pm. All electrical and electronic parts are carefully tested and calibrated before starting experiments. The experimental work was fully carried out on the roof of Fatima Mosque, Ali Town, Lahore.

Experiments were conducted on the Flatbed solar water heater to study the temperatures that it achieves during different days. The experimental tests on the solar water geyser were carried out on different days from 22th may 2019 till 29th may 2019. Each experiment starts from 10:00am-11:30am and 02:00pm-04:00pm. The experimental work is carried out on the roof of US Hostel Ali Town, Thokar Niaz Baig, Lahore.

During experiments, flatbed solar water geyser was placed in a position of 55degree so that the projection of sun rays falls directly upon the frontal face of solar collector. Water geyser was placed in the sun for several hours i.e. A time period long enough to ensure steady state conditions to prevail. Temperature of the collector was then recorded through a temperature probe.

η = Heat Energy Output / Heat Energy Input

$= Q_{out} / Q_{in}$

For calculating output Heat energy Q_{out} = Heat energy absorbed by water is $\rho \times V \times Cpw \times (Tf - Ti)$. P_{in} is taken as 1170 W/m^2.

$Q_{in} = P_{in} \times$area of panel$\times \Delta t$

V. Results and Discussion

These calculations have been performed for both SWHs for morning, afternoon and evening time and results are obtained in tabular as well as graphical form. The Solar Energy Factor is calculated to be 5.04049 as heat delivered to the system has been taken as 46064kJ/Day (given as per data by Meteorological Department) and parasitic energy is zero. For the sake of instance, a table and solar fraction results in graphical form have been shown as follows.

TABLE 1.
PERFORMANCE CALCULATIONS OF EVACUATED-TUBE SWH (MORNING)

Inlet Temp	Outlet Temp	Delta T	Solar Fraction	Q solar
17.2	68	50.8	0.91430338	90929
17.1	73	55.9	0.905699979	81855
16.1	78	61.9	0.895578331	73095
16	77	61	0.897096579	74299
19.7	81	61.3	0.896590496	73894
14.6	67	52.4	0.911604274	87892
17.8	78	60.2	0.898446132	75400
16.9	77	60.1	0.898614826	75539
17.4	77	59.6	0.899458296	76245
19.8	82	62.2	0.895072249	72701
19	77	58	0.902157403	78583
22	72	50	0.915652933	92520
21.5	68	46.5	0.921557228	100125
22.4	77	54.6	0.907893003	84007
19.7	92	72.3	0.878034142	61355
20.1	82	61.9	0.895578331	73095
25.1	74	48.9	0.917508569	94793
23.7	82	58.3	0.90165132	78135
22.4	78	55.6	0.906206062	82343
20.1	81	60.9	0.897265273	74435
21.2	81	59.8	0.899120908	75961
22.9	80	57.1	0.90367565	79956
23.2	82	58.8	0.90080785	77398
25.4	81	55.6	0.906206062	82343
27.1	79	51.9	0.912447745	88821
27.4	70	42.6	0.928136299	110072
29.6	76	46.4	0.921725922	100359
28.4	74	45.6	0.923075475	102270
22.9	69.2	46.3	0.921894616	100595
24.1	73	48.9	0.917508569	94793

These results have also been calculated for other phases of the day. A graphical representation is shown in figures 4 and 5 as per results obtained through calculations.

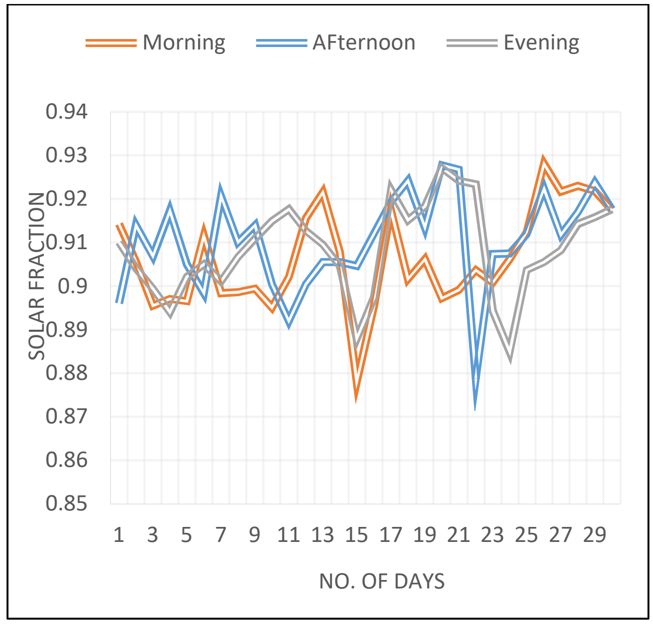

Figure 4. Solar Fraction analysis for Evacuated-Tube SWH. The values lie in the range of 0.87-0.93.

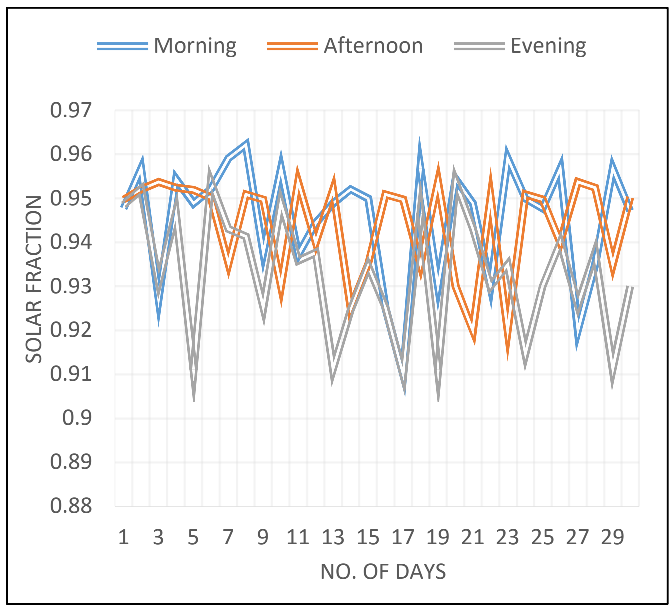

Figure 5. Solar Fraction analysis for Flatbed SWH. The values lie in the range of 0.9-0.97.

As shown in figures 4 and 5, the solar fraction values for Flatbed SWH are higher as compared to Evacuated SWH. It means that Flatbed SWH shows better performance characteristics. Also, a cost comparison has been conducted, Flatbed SWH designed by students of UOL costs almost 40% less than the commercial Evacuated-tube SWH, cost analysis being shown in table 2 (prices estimated in 2018). This means that Flatbed design can be utilized for household as well as domestic purposes as a cheaper and better alternative to commercial products.

TABLE 2.
COST COMPARISON (IN PKR)

Evacuated Solar Water Heater		Flatbed Solar Water Heater	
Machine cost	16000	Wood	500
Assembling	2000	Thermophore	500
Installation	4000	Silver Sheet & Pipe	4500
		Glass cover	2000
		Extra utilities	2500
		Tank & Glass Wool	1200
		Temp. Sensor	500
Total	22000	Total	11700

VI. CONCLUSIONS

For the sake of a cheaper machine for water heating purposes, a Flatbed Solar Water Heater has been compared with a commercial product (Evacuated-Tube SWH) on the basis of performance and cost. After mathematical calculations, the performance of Flatbed SWH comes out to be slightly better than Evacuated Tube SWH and also more than 50% cost is saved. This shows that Flatbed SWHs can be used as a cheaper alternative to Evacuated-tube SWH in countries like Pakistan. The efficiency of this design may be improved by considering following factors:

- This design may be improved by adding one or more absorbers (storage tanks), when water is heated in one cylinder, it will move to next cylinder and its temperature will be improved further. Initially we wanted to design such solar water geyser but there were cost issues.
- It is assumed that all days are clear (sunny) but practically it is impossible, so considering each day according to weather will be helpful in improving the efficiency
- It is considered the temperature of absorber and water same but there will also be few heats loses due to convection between absorber and water. So, the consideration of these loses will also help to decrease our efficiency loss.
- The insulating material also plays a major role for SWH's efficiency. As we used the wood sheet, if we use double ply wood, it will be more useful and efficient with Silver sheet.
- The reflectors of parabolic shape may also be used instead of rectangular box which will also further improve the reflection of light on absorber and consequently temperature will be increased.

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Time and Cost Overrun in Construction Projects of Pakistan

Asad Iqbal[1,*], Hafiz Saeed Ur Rehman[1], Moaaz Munir[1], Masood Ashiq[1] Adhban Omar[1], Zeeshan Haider[2]
Muhammad Akhtar[1], Musharaf Javed[1], Obaid Ur Rehman[1], Muhammad Adnan[1], Muhammad Jahanzaib[1]

[1]Civil Engineering Department, The University of Lahore, Lahore 54000, Pakistan
[2]Local Government & Community Development (LG&CD), Punjab, Pakistan

Corresponding author: A. Iqbal (e-mail: asadcivil03@gmail.com).

***Abstract*—According to this research, time and cost overruns in construction initiatives of Pakistan. So, carried out the qualitative questionnaire survey to collect the data for each time and cost invades. For distributing the questionnaire, I visited many construction businesses of Pakistan like National Engineering Services Pakistan (NESPAK), Construction & Works (C&W), National Logistics Cell (NLC) and many other non-public companies. Also, h designed the on-line filling questionnaire and used the net (social media) to distribute the questionnaire however the response is very inadequate. Distributed 70 questionnaires and capable to receive 50 questionnaires back. And used the SPSS software for evaluation of our questionnaire data and discovered the results. SPSS is a statistical package for beginning, intermediate, and superior statistics analysis. Also calculated the relative importance index (RII) for all trouble and as mentioned by outcomes have given the rank to each factor. Found the effects of questionnaire survey facts that the most integral element which is accountable for time overruns is '' delay in the economic guide by using proprietor to the contractor (stage with the aid of stage payment)'' having relative importance index (RII=0.796). Sometimes the consumer is neglecting his obligations to lift on the building challenge and shows his laziness to pay the "pay progress" to the contractor. This causes conflicts between the contractor and client; the work stops to pay development regulates. Find out the outcomes of a questionnaire statistics after analysis the most quintessential issue is "Change orders with the aid of owner in the course of construction", having a relative significance index (RII=0.756). When the client is interfering in the development initiatives again and again then it creates issues for contractors, employees and consultants then the task is struggling from time and cost overruns.**

***Index Terms*-- Cost, Contractor, Client, Consultant, Overrun, Relative Importance Index, Time.**

I. Introduction

The building enterprise shows a sizeable starring function in the cost-effective improvement of a country. Being a developing country, its position is of imperative importance in the improvement and financial system of Pakistan. When the development industry prospers the whole lot prospers". The postponement in the completion of construction projects is a global problem. In the construction industry, building prolong refers to the time overrun in detailed completion records or time overrun in the transport of the building undertaking on which all events agreed. [1]. The project's success depends on assembly goals inside time, cost, scope, and quality. So, time and value are vital parameters in measuring the success of the project. The construction projects around the world are inclined to time and value overrun. Construction delays can be defined as executing later than meant planned or a specific period, or later than the specified time that all the concerned parties agreed upon. For client/owner, it consequences in fee overrun, loss of productiveness, etc. In the case of a contractor, delay refers to the greater prices due to longer work periods, make bigger in labor fees and higher fabrication costs. It is very rare to see that a construction venture is performed on time. In this study, we mentioned the most imperative factors inflicting lengthen in building projects in Pakistan [2]. According to the team of contractor's escalations of fees is the huge component for delays. The consultants are blaming the bad supervision and mismanagement through the way of contractors. The common ranking comparison is indicating that Escalation of cloth prices, inadequate manipulate procedure, scarcity of technical persons, delays in work approval and shortage of materials, plant/equipment are most quintessential factors, these are in charge of developmental delays and fee overruns in Pakistan. Completing initiatives on time is an indicator of efficiency, on the other hand, the building manner is a mission to many variables and unpredictable factors, which end result from many sources. These sources include the common performance of parties, belongings availability, environmental conditions, the involvement of extraordinary parties, and contractual relations. However, it is now not frequently going on that a project is performed internally at a specific time [3]. The fundamental ambitions of the cutting-edge lookup locate out about are as follows:

1) To enlist factors affecting time overrun in building initiatives through evaluate of international and national level and then updating the listing of delay elements with recognize to the construction industry of Pakistan.
2) Ranking of these elements from the standpoint of a client, contractor, and consultant.
3) To make propositions for each party in the contract to mitigate the man or woman's contribution to time overrun.
4) To behavior a questionnaire survey in order to the response from professional of building development sector

II. Literature Review

Everywhere at some stage in the world, one-of-a-kind investigations have been embraced which shows that the development tasks are facing delays in their completion. At the factor when there is extended in the building projects, they are both facilitated or the booked time for the success of the task is expanded. The consequence is price overrun in both cases. Essentially, pronounced that price invade is the most widely identified influence of development prolongs in Nigeria. In the equal line, directed a study in Malaysia and presumed that fee overrun is positioned at the second number in the widespread effects of developmental delay. The explanation for fee overrun is the overtime fee which an agency wishes to stand to fulfill the work which comes about through postponement.

Further, the authors have concluded that as indicated by using contractual workers, value overrun is the profoundly positioned have an impact on the development industry. Time overrun is the precept purpose of price overrun. This is likewise upheld by using who presumed that agenda extent and price range overrun are straightforwardly identified with each other when there is time overrun in construction; a fee of that undertaking will additionally increase. Further, they said that at some point in the survey, respondents were of the point of view that because of delay, the development firms need to bear the greater fee of work, equipment, and instruments. Except for defaults of subcontractors at any level, the Contractor would possibly now not be in default as a result of any incapability to function this settlement beneath its terms if the disappointment emerges from motives outside the ability to manage and without the flaw or carelessness of the Contractor [4].

Project procurement structures (also called Project shipping methods) are used to define the venture company structure. Organization constructions for a building project are a framework of contractual and communication relationships between venture players. They are designed to supply development initiatives within time, price and first-rate [5] Construction Industry plays an essential position in the monetary development of any country as its activities are lengthy-term. Construction Industry constitutes 10% of world GDP. The Construction Industry of Pakistan constitutes 2.4% of GDP and its direct and oblique contribution to GDP and employment rank second to agriculture and manufacture in Pakistan. The attainable boom of the Construction Industry is hampered through a range of issues, the fee and time overruns being the most vital difficulty being faced through the Construction Industry of Pakistan. Though the reasons for fee and time overruns range from venture to project, its consequences in sheer wastage of time-delayed challenge benefits conceived at the time of project planning and monetary loss to the exchequer of the united states of America [6]. Construction initiatives require maximum utilization of manpower and development materials. A variety of participants are responsible for the successful execution of construction tasks as proven in Figure 1 [7].

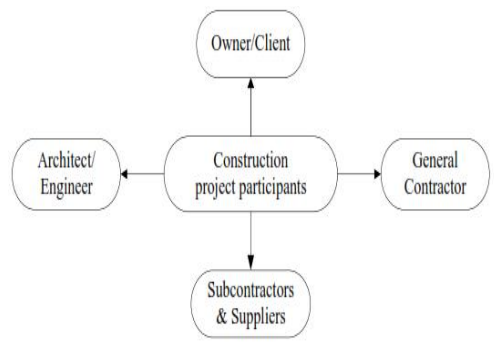

FIGURE 1. Project member for construction undertaking.

For ranking the critical factors of time overruns we have found the Relative Importance Index (RII). Since,

$$RII = \frac{\sum W}{A * N} (0 \leq RII \leq 1)$$

where, W is the weight given to each component through the respondents and the vary is used from 1 to 5 (where ‘’1’’ is now not significant, ‘’2’’ is slightly significant, ‘’3’’ is slightly significant, ‘’4’’ is very enormous and ‘’5’’ is extremely significant)

Note: This notation is used for evaluation solely A = is the best weight (i.e. 5 in this case)

N = is the total variety of respondents [8,9]

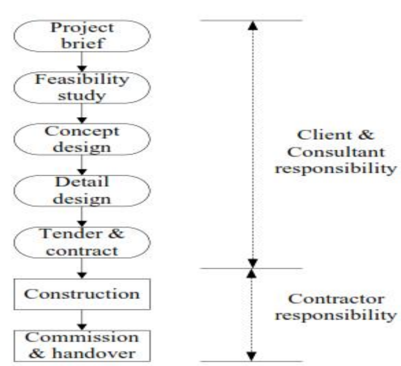

FIGURE 2. Process of traditional procurement method over the project life cycle.

III. Research Methodology

From the literature assessment, we have studied about the one of a kind projects that have not been performed on the scheduled period given to the exact project. So, due to this reason, the tasks are facing price overruns also. We have studied about the essential motives of delays and identified the principal elements that are influencing on time and price overruns. The building tasks delegates to the time overruns the assignment completion beyond the date on which parties are agreed. From the literature review, we have discovered many tasks that have been confronted with visa fees and time overruns. Some of them are as follows: In Hong Kong, the major reasons of fee and time overruns are an unpredictable website online conditions, bad management, and supervision at some stage in construction, sluggish selection making with the aid of client, guide and contractor and changing of work after the start of the project. In Nigeria the most essential motives of time and value overruns are bad handling of contract clauses, payment, and finance issues, deficiency of materials and equipment's, wrong estimations and changing in fees In Pakistan, it is the especially unique case that expansive development assignment is finished on the time. There are several massive improvement ventures in Pakistan, which persevered prolong or at instances persisted suspension or relinquishment.

A few cases of expansive improvement ventures, which endured defer or enduring postponement are: Reconstruction of Earthquake influenced streets; copy of Floods influenced streets, China mechanical urban communities in Punjab, Sindh, Khyber-Pakhtunkhwa and Baluchistan, Port tower complex by way of KPT, Motorways of Pakistan, National Highways of Pakistan, Kalabagh Dam and so on.

There are two kinds of the questionnaire. Research techniques and exploration records in intelligence research can be set into necessary classes: Quantitative and Qualitative. Qualitative examination assembles facts that are no longer in the numerical structure. For instance, journal accounts, open-finished polls, unstructured meetings, and unstructured perceptions.

Qualitative records are typically attractive facts and for this reason, it is more difficult to have a look at than quantitative information. Quantitative exploration accumulates statistics in a numerical structure that can be put into classes, or in a rank request, or measured in gadgets of estimation. This form of statistics can be utilized to build diagrams and tables of crude information. Questionnaires are an extensively utilized statistics gathering approach yet outlining a respectable survey is no longer commonly simple.

The Designing and making use of surveys as a part of your exploration session will take you through the phases of the questionnaire sketch and will give a pragmatic course on issues, for example, the enchantment and wording of inquiries, guiding and examination.

A listing of useful books and web sites about designing and using questionnaire. In our lookup, we have used all these assets whilst designing of questionnaire associated with time and value overruns in the development industry of Pakistan.

A. Interviewing Skills of the Researcher

Talking with aptitudes for specialist's session covers the procedure of making arrangements for meetings, making contacts, convincing individuals to participate, and issues around face to face meeting

B. Questionnaire Survey

According to our project time and cost overruns in construction projects of Pakistan, for distributing the questionnaire, we have visited many construction companies of Pakistan like National Engineering Services Pakistan (NESPAK), Construction & Works (C&W), National Logistics Cell (NLC) and many other private companies. Also, we have designed the online filling questionnaire and used the internet (social media) to distribute the questionnaire but the response is very inadequate. We have distributed 70 questionnaires and able to receive 50 questionnaires back.

C. Analysis of Questionnaire Data

Here we have used the SPSS software for analysis of our questionnaire data and found the results [10]

IV. Results and Discussion

A. Respondents Characteristics

This section includes that the questionnaire was designed to have details about the respondent such as the name of the respondent, company name, address, city/town, e-mail address, designation, etc.

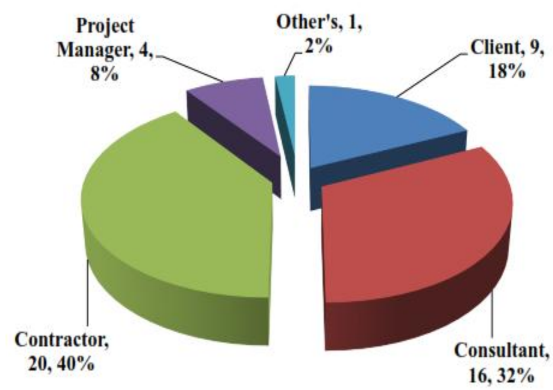

FIGURE.3. Types of respondents.

B. Factors Influencing Time Overruns

The first ten critical factors that are influencing time overruns in the construction industry of Pakistan. The following table shows the results according to the questionnaire data.

TABLE 1. Critical factors of time overrun

Sr. No.	Factors	RII	Rank
1	Delay in financial support by the owner to the contractor	0.796	1
2	Design changes by the owner or his agent during construction	0.768	2
3	Preparation and approval of shop drawings	0.752	3
4	Lack of coordination among project teams	0.720	4
5	The discrepancy between design specification and building code	0.656	5
6	Poor material procurement planning	0.652	6
7	Shortage of unskilled & skilled labor	0.632	7
8	Bad weather conditions /Natural disasters (flood, earthquake)	0.608	8
9	Slowness in decision making	0.600	9
10	Lack of communication between parties	0.596	10

TABLE 2: Client related factors for time overrun

Sr. No.	Factors	Contractor		Consultant		Client		Average	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Delay in financial support by the owner to the contractor (Stage by stage payment)	0.90	1	0.75	1	0.69	2	0.78	2
2	Shortages of materials on site	0.57	4	0.49	6	0.62	4	0.56	5
3	Late delivery of material	0.51	6	0.51	5	0.62	5	0.55	6
4	Lack of communication between parties	0.53	5	0.58	4	0.69	3	0.6	3
5	Design changes by the owner or his agent during construction	0.88	2	0.74	2	0.76	1	0.79	1
6	Slowness in decision making	0.57	3	0.64	3	0.53	7	0.58	4
7	Delays in obtaining approval from the municipality	0.49	7	0.46	7	0.56	6	0.50	7

TABLE 3. Consultant related factors for time overrun

Sr. No.	Factors	Contractor		Consultant		Client		Average	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Lack of coordination among project teams	0.69	2	0.74	1	0.80	1	0.74	1
2	Poor material procurement planning	0.72	1	0.59	3	0.58	4	0.63	3
3	The discrepancy between design specification and building code	0.67	3	0.61	2	0.76	2	0.68	2
4	Insufficient data collection and survey before the design	0.63	4	0.56	4	0.56	5	0.58	5
5	Lack of experience of consultant in construction projects	0.54	5	0.54	5	0.76	3	0.61	4
6	Improper project feasibility study	0.53	6	0.54	6	0.56	6	0.54	6

TABLE 4. Contractor related for time overrun

Sr. No.	Factors	Contractor		Consultant		Client		Average	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Receiving materials that do not fulfill standards	0.50	4	0.55	2	0.58	5	0.54	3
2	Equipment failure or breakdown	0.41	6	0.54	4	0.40	6	0.45	6
3	Unskilled equipment operators	0.44	5	0.55	3	0.64	2	0.54	5
4	Preparation and approval of shop drawings	0.75	1	0.71	1	0.84	1	0.76	1
5	Shortages of materials on site	0.57	2	0.49	6	0.62	3	0.56	2
6	Late delivery of material	0.51	3	0.51	5	0.62	4	0.54	4

TABLE 5. External Factors for time overrun

Sr. No.	Factors	Contractor		Consultant		Client		Average	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Accidents during construction	0.54	3	0.50	4	0.42	7	0.49	4
2	Disputes during construction	0.50	4	0.50	5	0.42	6	0.47	5
3	Strike	0.48	6	0.55	3	0.47	5	0.50	3
4	Changes in government regulations and laws	0.39	8	0.50	6	0.49	4	0.46	7
5	Bad weather conditions /Natural disasters (flood, earthquake)	0.63	1	0.68	1	0.56	2	0.62	2
6	Geological problems on site	0.41	7	0.45	7	0.56	3	0.47	6
7	Personal conflicts among workers	0.50	5	0.35	8	0.33	8	0.39	8
8	Shortage of unskilled & skilled labor	0.55	2	0.68	2	0.69	1	0.64	1

TABLE 6. Critical factors of cost overrun

Sr. No	Factors	RII	Rank
1	Change order by owner during construction	0.756	1
2	Inaccurate bills of quantities	0.74	2
3	Planning and scheduling deficiencies	0.712	3
4	Fluctuation of prices	0.7	4
5	Late in reviewing and approving design documents by consultant	0.688	5
6	Cash flow during construction	0.68	6
7	Low bid	0.664	7
8	Deficiencies in cost estimates prepared	0.66	8
9	Escalation of material prices	0.656	9
10	Low productivity of labors	0.592	10

TABLE 7. Client factors of cost overrun

Sr. No.	Factors	Contractor		Consultant		Client		Average	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Delays in work approval	0.51	5	0.54	5	0.51	6	0.52	5
2	Waiting for information related to the complexity of the project	0.40	6	0.41	6	0.53	5	0.45	6
3	Cash flow during construction	0.69	3	0.65	3	0.76	2	0.70	2
4	Late delivery of materials and equipment	0.55	4	0.60	4	0.53	4	0.56	4
5	Low bid	0.69	2	0.65	2	0.71	3	0.68	3
6	Change orders by the owner during construction	0.81	1	0.71	1	0.82	1	0.78	1

TABLE 8. Consultant related factors of cost overrun

Sr. No.	Factors	Contractor		Consultant		Client		Average	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Deficiencies in cost estimates prepared	0.77	2	0.65	3	0.47	5	0.63	4
2	Late in reviewing and approving design documents by consultant	0.76	3	0.60	4	0.80	1	0.72	3
3	Planning and scheduling deficiencies	0.71	4	0.78	1	0.73	3	0.74	2
4	Inaccurate bills of quantities	0.78	1	0.73	2	0.76	2	0.76	1
5	Design errors made by designers due to unfamiliarity with local conditions & environment	0.50	5	0.60	5	0.49	4	0.53	5

TABLE 9. Contractor related factors of cost overrun

Sr. No.	Factors	Contractor		Consultant		Client		Average	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Mistakes during construction	0.51	3	0.63	2	0.56	3	0.57	2
2	Frequent breakdowns of construction plant and equipment	0.50	4	0.59	5	0.60	2	0.56	4
3	Labor shortages	0.48	6	0.61	3	0.47	7	0.52	7
4	The low productivity level of labors	0.64	1	0.55	7	0.56	4	0.58	1
5	Inadequate contractor's experience	0.44	7	0.65	1	0.62	1	0.57	3
6	Rework due to errors during construction	0.55	2	0.56	6	0.51	6	0.54	6
7	Choice of wrong construction method	0.50	5	0.60	4	0.56	5	0.55	5

TABLE 10. External factors related to cost overrun

Sr. No.	Factors	Contractor		Consultant		Client		Average	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Fluctuation of prices	0.75	1	0.61	1	0.80	1	0.72	1
2	Shortage of materials, Plant/equipment parts	0.54	4	0.49	6	0.60	4	0.54	4
3	Difficulties in obtaining construction materials at official current prices	0.58	3	0.55	3	0.71	2	0.61	3
4	Escalation of material prices	0.72	2	0.61	2	0.67	3	0.66	2
5	Traffic control and restriction at the job site	0.39	7	0.49	7	0.40	6	0.43	7
6	Ground problems	0.47	5	0.51	5	0.42	5	0.46	5
7	Unexpected geological conditions	0.47	6	0.53	4	0.40	7	0.46	6

V. Conclusions

According to our task time and price overruns in building initiatives of Pakistan we have carried out the qualitative questionnaire survey to gather the records about the time and fee overruns. For distributing the questionnaire, we have visited many development agencies of Pakistan like National Engineering Services Pakistan (NESPAK), Construction & Works (C&W), National Logistics Cell (NLC) and many different personal companies. Also, we have designed the online filling questionnaire and used the net (social media) to distribute the questionnaire but the response is very inadequate. We have dispensed 70 questionnaires and, in a position, to receive 50 questionnaires back. We have used the SPSS software for analysis of our questionnaire records and observed the results. SPSS is a statistical package for beginning, intermediate, and advanced information analysis. We have calculated the relative importance index (RII) for everything and in accordance with outcomes, we have given the rank to each factor. We have found the results of the questionnaire survey facts that the most fundamental component which is responsible for time overruns is ‘’ delay in economic support by way of the owner to the contractor (stage by means of stage payment)’’ having relative importance index (RII=0.796). Sometimes the consumer is neglecting his obligations to lift on the construction undertaking and suggests his laziness to pay the “pay progress” to the contractor. This motives conflicts between the consumer and contractor and the work stops to pay growth regulates. This results in the extent of the development projects. The 2d element is additionally associated with the client having a relative importance index (RII=0.768). During building the customer is now not feeling relief with the diagram and changes once more and again these reasons to lengthen the project. The third vital thing is patron associated guidance and approval of saving drawings having a relative importance index of (RII=0.752). When the contractor has failed to prepare store drawings the venture is going through delays. In the pinnacle, ten vital factors accountable for time overruns the remaining aspect is lack of communication between the projects for the duration of construction having relative importance index (RII=0.596). We have located the consequences of questionnaire information after analysis the most vital component is “Change orders through proprietors all through construction”, having relative importance index (RII=0.756). When the client is interfering in the building projects again and again then it creates issues for contractors, people and consultants then the assignment is suffering from time and value overruns. The 2nd most crucial element is “Inaccurate bills of quantities”, having a relative significance index (RII=0.740). If the guide makes mistakes in a bill of quantities (BOQ, s) then the soft and bid filling is according to that BOQ. If the unsuitable BOQ is much less than the accurate then the mission will face price overruns. The 0.33 essential issue is “Planning and scheduling deficiencies”, having a relative importance index (RII=0.712). Great planning and scheduling is a key factor in the success of any project. If the deficiencies in planning and scheduling then the project may face time and price overruns.

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Utilization of Copper Slag in Bituminous Mix

Asad Iqbal[1*], Awais Basharat[2], Shahid Ali[2]

[1]Department of Civil Engineering, The University of Lahore, Lahore
[2]Department of Civil Engineering, National University of Computer and Emerging Sciences, Lahore
[*]Corresponding Author: Asad Iqbal (asadcivil03@gmail.com)

ABSTRACT-- There is a huge demand of aggregates for the construction of roads and concrete constructions in Pakistan. The construction of roads for high-speed traffic and heavy axle loads put enormous pressure on road materials. Many public sectors as well as private organizations are carrying out a wide range of research projects on the environmental, feasibility, and economic performance of using industrial waste products in the construction of roads. This study is attempted to fulfill the needs of society in the safe and economical disposal of waste material. This research aims to explore the potential use of copper slag (CS) as a replacement of fine aggregate and filler material. Comparison of conventional HMA samples and HMA samples having some percentage of copper slag as a replacement of fine aggregates. First, test aggregates and bitumen with 0% copper slag to determine their mechanical properties. Make samples and add bitumen percentage (3.5%, 4%, 4.5%, 5%, and 5.5%). Copper slag was added with 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40% by weight. In the end, the tests were performed on the Marshal Apparatus. The experimental results showed that the addition of 20% of copper slag as fine aggregates has maximum Marshall Stability, a higher flow rate, maximum VFB and specific gravity slightly increases as compare to conventional HMA. Therefore, the strength is maximum by the addition of 20% copper slag, so we can use it in heavy traffic lanes and runways. Copper slag is economical as compared to other fine aggregates, so it should be implemented in Pakistan. Sufficient research has been conducted in Pakistan since it's not being implemented frequently. Therefore, we have some solid reasons, conclusion and recommendations in this research.

Index terms—Copper Slag,Hot Mix Asphalt,Aggregate,Bitumen,Stability

I. INTRODUCTION

Many countries are witnessing rapid growth in the construction sector, involving the use of natural resources for infrastructure development. To check & improve the performance of HMA addition of mineral filler & fine aggregates plays an important role. It is constantly compromised by the lack of available natural resources as aggregates are considered one of the important constituents of concrete. Lack of natural resources can be compensating by waste recycling of different raw materials. In recent decades, many environmental problems have been raised in a large amount of waste produced by industries. As these are producing waste products, such as acids, alkalis, oils, scrap metal, fly ash, slags, rubber waste, stone chips and various types of powders [1]. The main purpose of environmental protection agencies and government is to use the by-products/raw material in a safe way because of increasing population, industries, technology, and development [2]. On the other hand, recycling of waste avoids oversaturation of landfills, which also contributes to protecting the environmental problems [3].The reuse of waste material in road construction saves energy and natural resources [4]. The use of raw materials from industrial waste can be an alternative to aggregates & mineral fillers [5].Copper slag (CS) is the by-product which is obtained from the refining and smelting of copper material as it is classified as waste, therefore it is considered an environmental problem. Copper Slag can be used effectively for pavement construction that could have a promising future in the construction industry [6].Copper slag is granular solids, ranging from 0.2 mm to 3 mm, in the form of fine aggregates. A mixture of viscous black hydrocarbons obtained in the form of residue of petroleum distillation. As a result, many contemporary types of research have the been focusing on the application of copper slag in a bituminous mix as it offers benefits in environmental and economically, especially in those areas where a significant quantity of copper slag is produced [7]. Currently, a large number of roads are being constructed under the China-Pakistan Economic Corridor (CPEC) project in which assurance of road quality to stand with heavy traffic loads is a major concern.so, it is necessary to see the behavior of fillers & fine aggregates in the design process of HMA. This research objects to relate properties of conventional HMA samples and HMA samples having some percentage of (CS) in replacement of filler materials & fine aggregates. The main study of research is to improve the performance of HMA by using copper slag in 60/70 grade bitumen.

II. LITERATURE REVIEW

Copper slag is classified as waste; therefore it is considered an environmental problem. It can be used effectively for pavement construction. In order to save energy, material and reduce the amount of pollutants released during asphalt production. [8]. The influence of the replacement of aggregates by copper slag on the performance of HMA and Optimum binder (O.B.C) contents of mixes containing CS proportions of 0, 10, 20, 30 and 40% in total weight of the aggregates were determined using the Marshall procedure tests showed that 20% of CS in HMA improves Marshall Stability, Flow, and bitumen content [9].Copper slag is used as fine aggregate by varying the percentage of 20%, 30% and 40% with bitumen content and aggregate. The Marshall test was considered for the design of mixtures such as stability, voids filled aggregate, flow value, voids filled bitumen (VFB), air voids, and optimum bitumen content (OBC) was found suitable at CS 20% [10]. Copper slag is produced during the extraction of the metal from its ore. Copper slag is a non-plastic coarse grain material having a high CBR value of up to 70% and good permeability [11].Each year, the production and refining process of copper produces a large volume of CS and disposal of its waste remains an environmental problem.so, its annual production leads to an increase in volume and number of landfills which contains metals such as Pb, Cu, SO2, and Hg. The results showed that by addition of 20% CS is favorable as stability and flow values increases [12].Copper slag (CS) was used as a fine aggregate (up to 40%). The addition of Copper Slag, as fine aggregate in various bituminous mixtures, that makes it possible to obtain a good interlocking and possibly improves the volumetric and mechanical properties of the bituminous mixture [13]. Wastes such as zinc slag, copper slag & steel slag were examined for their suitability for road pavements, while zinc slag and Copper Slag can be used as a partial replacement in bituminous layers. The density of copper, zinc and steel slags ranged from 2.75 to 3.6 [14].The use of plastic scrap and copper slag in hot bituminous mixes to improve pavement performance. Mineral aggregate samples are also prepared with a Copper Slag composition (10%, 20%, 30% and 40%) [15]. Marshall Stability and bulk specific gravity increase with bitumen content, after which these two parameters starts decreasing. But the value of the flow increases with the bitumen content. In the same way, the air gap decreases with increasing bitumen content. [16].By Addition of Copper Slag has a significant role in increasing the stability and flow of HMA Mix [17]. From the above literature, it has been observed that Copper slag has been suggested as a fine aggregate in limited quantities for bituminous mixes but not as an alternative to aggregate asphalt.

III. RESEARCH METHODOLOGY

Firstly, test aggregates and bitumen with 0% copper slag to determine their mechanical properties. Classify aggregates in NHA Class "A" gradation. Then make samples and add bitumen percentage (3.5%, 4%, 4.5%, 5%, 5.5%).Copper slag is added with 5%, 10%, 15%, 20 %, 25%, 30%,35%,40% by weight of fine aggregates to the five sets of mixtures and the same procedure is repeated for each. In the end, the tests are performed on the Marshal Mix apparatus to achieve the best volumetric properties of Marshall Mix by the addition of Copper Slag. The following tests are performed shown in Table 1

TABLE 1. EXPERIMENTS PERFORMED

Aggregates test	Bitumen test
Sieve Analysis	Marshal stability & flow test
Loss Angeles Abrasion	Flash & Fire point
Impact Value	Softening Point
Specific Gravity	Penetration Test
Water Absorption	Specific gravity

FIG 1. SAMPLES OF HMA

FIG 2. SAMPLES OF CS WITH ASPHALT MIX

FIG 3.SAMPLES IN WATER BATH

FIG 4.SAMPLE IN MARSHALL APPARATUS

IV. RESULTS

The design mixes contain coarse aggregate, fine aggregate and stone dust. The fine aggregate and mineral filler proportion were replaced at 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40% by copper slag. The bitumen content was varied at 3.5%, 4%, 4.5%, 5% and 5.5% for various design mixes. The summary of the experimental results is presented in tables 2, 3 and 4. The performance of specimens has been checked by conventional samples. To fulfill the criteria of Marshall Mix Design addition of asphalt content was added from 3.5% to 5.5% with a positive increment of 0.5%.

TABLE 2. PHYSICAL PROPERTIES OF AGGREGATES

Sr #	Material properties	Specifications	Results	Range
1	Crushing Strength	B.S 812 & IS 383	6%	< 15%
2	Flakiness	ASTM D 4791	12.21%	< 15%
3	Angularity No	ASTM D 4791	08	0-11
4	Water Absorption	AASHTO T 85-88	0.29%	Max 2%
5	Specific Gravity	AASHTO T 85-88	2.69	2.5-3
6	Elongation	ASTM D 4791	11.82%	<15%
7	Impact Value	BS 812 & IS 383	8.17%	<10%
8	Abrasion value	ASTM C535 AASHTO T96	16%	<40%

TABLE 3. PHYSICAL PROPERTIES OF ASPHALT

Sr #	Physical Properties	Specifications	Results	Range
1	Asphalt Grade	AASHTO T49	60/70	60/70
2	Softening Point	AASHTO T53-89	42 ^{O}C	30-157 ^{O}C
3	Fire Point	ASTM-D-92(C)	268 ^{O}C	260-290 ^{O}C
4	Flash Point	ASTM-D-92(C)	248 ^{O}C	240-260 ^{O}C
5	Ductility Test	AASHTO T179	73cm	60-85cm
6	Penetration at 25^{O}C	AASHTO T49	64mm	50-70mm

TABLE 4. AVERAGE OPTIMUM BINDER CONTENT (OBC %)

Test Properties	HMA %	5% CS	10% CS	15% CS	20% CS	25% CS	30% CS	35% CS	40% CS
Max Stability at B.C	5%	5%	5%	5%	5%	5%	5%	5%	5%
Max Bulk Sp. Gravity at B.C	5%	5%	5%	5%	5%	5%	5%	5%	5%
B.C at 4% air voids	4.55	4.65	4.81	4.90	4.93	4.75	4.68	4.60	4.53
Avg OBC %	4.85%	4.88%	4.93%	4.96%	4.97%	4.92%	4.89%	4.86%	4.84%

TABLE 5. COMPARISON OF CONVENTIONAL HMA AND HMA WITH DIFFERENT % OF COPPER SLAG

Mix	HMA %	5% CS	10% CS	15% CS	20% CS	25% CS	30% CS	35% CS	40% CS
OBC (%)	4.85	4.88	4.93	4.96	4.97	4.92	4.89	4.86	4.84
Air Voids (%)	3.9	3.51	3.92	4.11	4.15	3.92	3.62	3.5	3.39
Flow-0.01(inch)	11.3	9.22	10.9	11.11	11.52	10.82	10.39	9.62	9.25
Specific Gravity	2.409	2.391	2.421	2.441	2.471	2.487	2.499	2.521	2.548
Stability (kg)	922.5	820.25	852.23	915.1	1025.25	935.22	912.22	885.92	850.22
VFB (%)	71.8	72.1	72.52	72.9	73.3	72.5	72.1	71.8	71.4

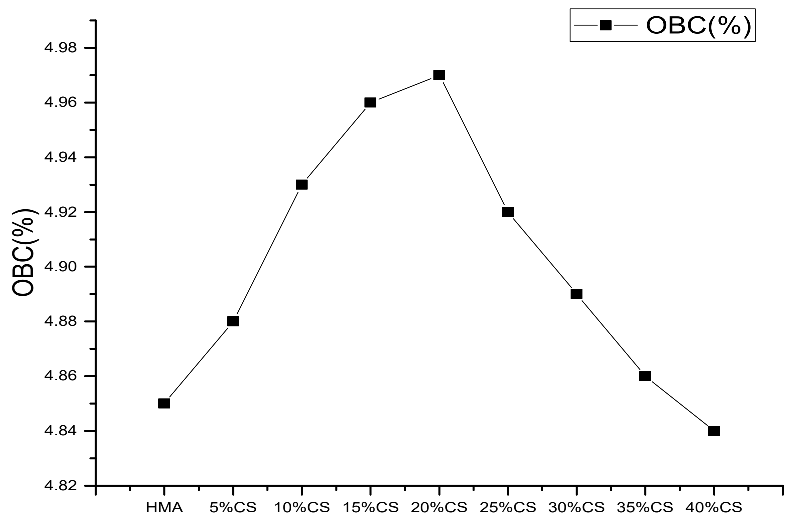

FIG 5.COMPARISON OBC OF HMA AND COPPER SLAG SAMPLES

OBC comes out to be a maximum of 4.97 at 20% CS than all other percentages of copper slag and conventional HMA.

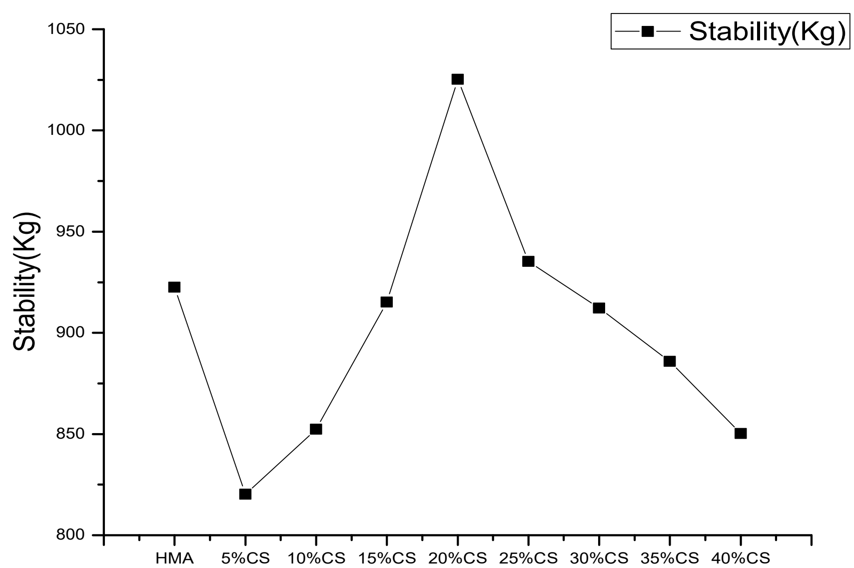

FIG 6.COMPARISON STABILITY OF HMA AND COPPER SLAG SAMPLES

The value of stability at 20% copper slag is a maximum of 1025.25kg as compare to all other percentages of copper slag and conventional HMA.

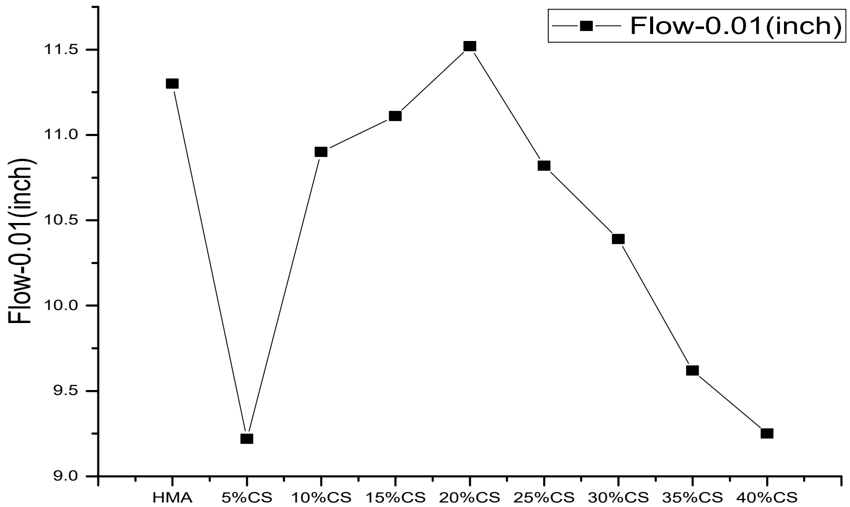

FIG 7.COMPARISON FLOW OF HMA AND COPPER SLAG SAMPLES

The value flow is at 20% copper slag is a maximum of 11.52mm as compare to all other percentages of copper slag and minimum when compared with conventional HMA.

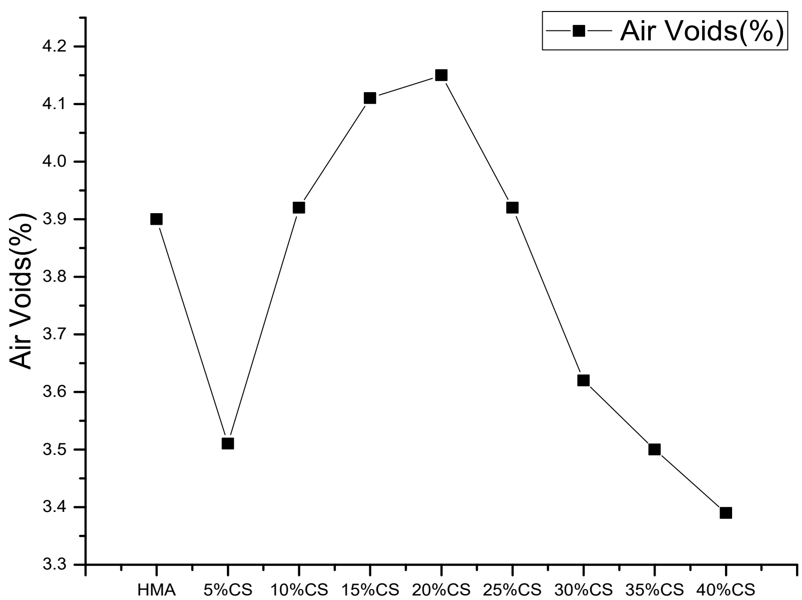

FIG 8.COMPARISON AIR VOIDS OF HMA AND COPPER SLAG SAMPLES

The value of Air voids is at 20% copper slag minimum 4.15% as compared to all other percentages of copper slag and little higher when compared with conventional HMA.

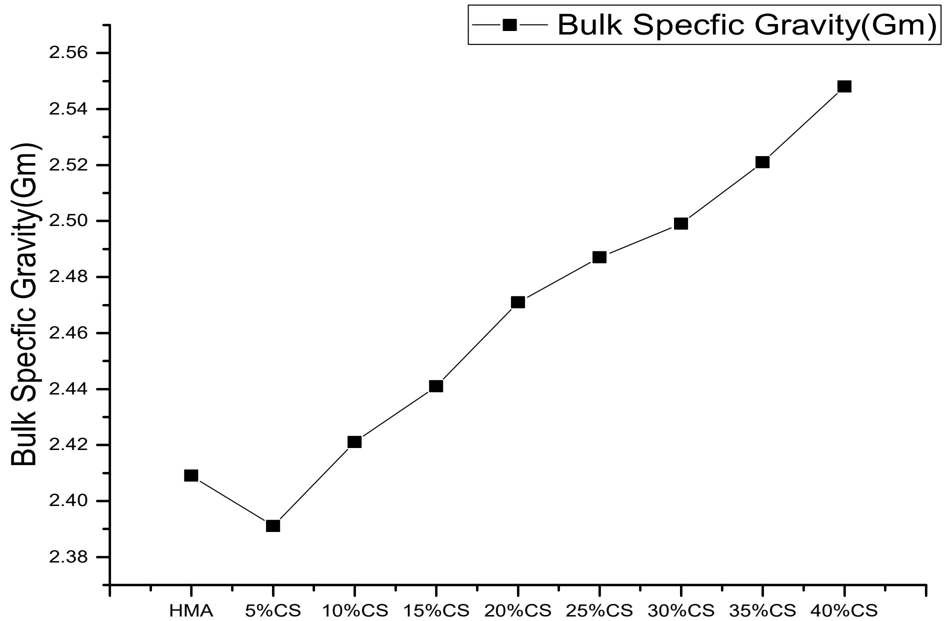

FIG 9.COMPARISON BULK SPECIFIC GRAVITY OF HMA AND COPPER SLAG SAMPLES

The value of Bulk Specific Gravity is increasing as the percentage of copper slag increases. Bulk Specific Gravity of Copper Slag is 3.30.

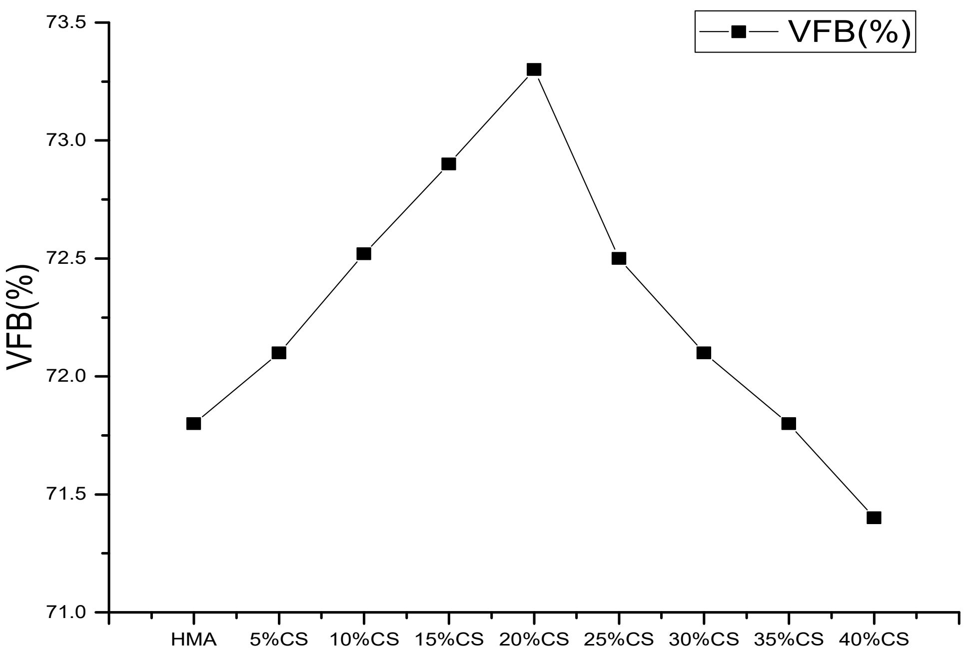

FIG 10.COMPARISON OF VFB OF HMA AND COPPER SLAG SAMPLES

The VFB is at 20% copper slag maximum 71.5% as compared to all other percentages of copper slag and it's slightly minimum compared with conventional HMA.

V. CONCLUSIONS

The Marshall Stability value for the addition of 20% copper slag is more than 5%, 10%, 15%, 25%, 30%, 35%, 40% and conventional HMA samples. The value of the flow increases with the addition of 20% copper slag. It decreases by 20% to 40%. It is slightly higher than conventional HMA. The value of OBC increases with the addition of a 20% copper slag. It begins to decrease by 20% to 40%. Bulk specific gravity increases with an increasing percentage of copper slag because copper slag has a high specific gravity. The value of VFB at 20% copper slag is maximum compared to all other percentages of copper slag. The value of the air voids at 20% of copper slag is maximum after it begins to decrease.

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Influence of Austempering Heat Treatment on Ductile Iron

M. Ashraf Sheikh

[1]Department of Technology, The University of Lahore, Lahore, 54000, Pakistan
Corresponding author: First A. Author (e-mail: author@ee.uol.edu.pk).

***Abstract*-In this present work the influence of austempering heat treatment was studied on ductile iron. Medium frequency induction furnace was used to make casting samples. Austempered Ductile Iron (ADI), which is a relatively new material is produced by the process of austempering heat treatment. ADI material is a very valuable. The properties of ADI are equivalent to forged steel. This study was done to develop Austempered Ductile Iron and to find out the effect of heat treatment temperature. In this study samples were treated, one with higher heat treatment temperature i.e. 370 ^{0}C and other in lower range of temperature i.e. 285 ^{o}C were used. For austenitizing of samples, the furnace temperature was maintained at 900 ^{o}C and the samples were heated for one hour. After austenitizing, the samples were dipped in a salt bath at temperatures i.e. 285 ^{o}C and 370 ^{o}C for one hour. The researcher found encouraging result. Almost double tensile strength was achieved with the same composition of the samples only with the heat treatment at lower temperature.**

***Index Terms*-- Austempering, Ductile iron, Induction furnace, Tensile strength, Astatized**

I. INTRODUCTION

Ductile iron shows good ductility and toughness because the shape of graphite is spherical in the ductile iron [1]. Applications of ductile iron castings are many especially those requiring a material having good machinability and strength. Ductile iron is used mostly for the production of auto parts i.e. crankshafts, piston rings and cylinder lining. Cost of ductile parts are less than the cost of parts of steel or malleable iron [2].

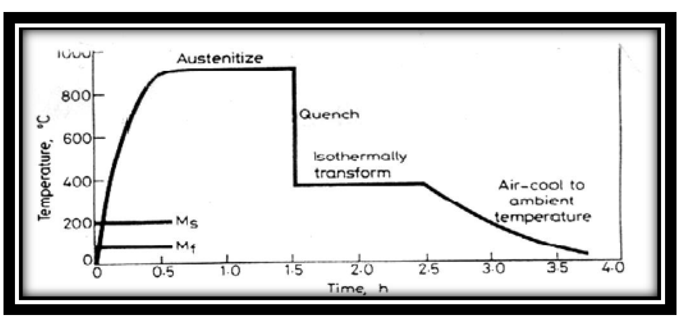

Figure 1. Heat treatment cycle for austempering [8]

If ductile iron is austempered at controlled temperature, it is changed to Austempered Ductile Iron (ADI) with unique properties comparable to forged steel. To convert the ductile iron to austempered ductile iron (ADI) is not a very hard job. Its primary requirement is that the ductile iron chosen for ADI should be of good quality [3]. Engineers are paying attention to ADI because of its attractive properties e.g. ductility, wear resistance, tensile strength and fatigue property [4]. Design engineers are preferring ADI material than steel due to its low cost and good machinability. It also has high strength-to-weight ratio of the material [5]. Due to its less weight and less price ADI has become a substitute material for aluminum alloys and steel [6]. ADI parts have replaced many castings of steel and forged parts [7].

ADI is made by special austempering heat treatment process [8]. The process is shown in figure 1 and it is summarized as follows:

1) To convert the simple ductile iron parts to ADI parts, these are heated to 850 ^{o}C to 950 ^{o}C, austenitizing temperature.
2) These parts are held at this temperature to saturate the austenite with carbon for requisite time.
3) Then the austenitised parts are quenched quickly to the range of 235 ^{o}C to 400 ^{o}C which is called austempering temperature.
4) The parts are held at this austempering temperature for required time to get the desired properties and microstructure of the parts.
5) The ADI parts produced are then cooled to room temperature.

II. ADI SPECIFICATIONS

The ASTM has made five grades for ADI, which is mentioned in table 1 [9]. The grades are made considering their mechanical properties e.g. tensile strength and hardness. These grades are now used by engineers and professionals.

In recent years the ADI is the exceptional achievement in the material of cast iron. The simple heat treatment makes the material very useful for many applications with good strength and with sufficient ductility. The researchers are continuously working on different aspects of this unique material. The purpose of this study was to investigate the influence of heat treatment (austempering) on tensile strength. For this purpose, a high range and a low range austempering temperatures were chosen.

Table I

ASTM A897-90, ADI Specification.[9]

Grade	Tensile Strength (Min)		Yield Strength (Min)		Elongation	Brinell Hardness
	Psi.	N/mm²	Psi.	N/mm²	%	Range
1	125,000	850	80,000	550	10	269-321
2	150,000	1050	100,000	700	7	302-363
3	175,000	1200	125,000	850	4	341-444
4	200,000	1400	155,000	1200	1	388-477
5	230,000	1600	185,000	1300	-	444-555

III. Experimental Procedure

A. Research Methodology

The purpose of this research was to find the influence on ductile iron of the heat treatment (austempering). For this purpose, medium frequency induction furnace was used to produce samples from as-cast pieces. The cast samples were machined and first heated for one hour in a muffle furnace at 900 ^{0}C temperature. Then the samples were quickly submerged in a salt bath kept at temperature 285 ºC. Another batch of samples were dipped in salt bath maintained at temperature 370 ^{0}C, i.e. at a higher range. After this heat treatment process (austempering), the tensile strength of samples was found using universal tensile strength machine.

B. Equipment

Induction Furnace: Induction furnace of capacity 30 kg was used for the melting of charge. Good quality raw materials were used for the production of ductile iron. Twenty-four-kilogram melt was used for each experiment.

Spheroidizing Treatment Ladle: A special ladle with two pockets at the bottom was used to convert the cast iron into ductile iron. Ferro alloys of ferro-silicon 75 and ferro-silicon-magnesium were placed in one of the pockets at bottom and another pocket was empty. Now the melted metal was poured to this ladle. Using this method, the cast iron was converted to ductile iron.

Heat Treatment Furnaces: Two heat treatment furnaces were used; one for austenitizing and other for austempering. Austenitizing of castings were done in a muffle furnace. The maximum temperature of the furnace was1300 ºC.

Vertical tube furnace: The other heat treatment furnace was for austempering. It was a Carbolite vertical tube furnace with maximum temperature of 1200 ºC. The casting samples were immersed in salt bath for austempering heat treatment.

Universal Testing Machine: After the austenitizing and austempering heat treatment, the samples were subjected to tensile test. The maximum capacity of the universal testing machine was 100 kn.

C. Casting of Ductile Iron Samples

The ductile iron tensile samples were cast in an induction furnace of medium frequency. The raw materials were iron from local market, Sorel metal and ferro-alloys. The method used for casting of tensile samples was sandwich method. In this process a special type of ladle was used in which the ladle was provided at the bottom two pockets. One of the pockets was filled with ferro-alloys while the other pocket was empty. The composition of casting samples was as follows:

Table II

Composition of Casting Samples Wt. %

C	Si	S	P	Mg	Fe
3.5	2.5	0.05	0.008	0.5	Balance

Table III

Effect of Heat Treatment on Ductile Iron

Austenitizing Temperature ^{0}C	Austempering Temperature ^{0}C	Elongation %	UTS N/mm²
900	285	3.2	1657
900	370	5.0	1154
Without Heat Treatment	------	12.3	714

IV. Results and Discussion

The tensile strength of the samples was found after the heating the samples for one hour at 900^{0}C and then dipping samples quickly to furnace for one hour at 285 ^{0}C. The second batch of samples were heated at 900 ^{0}C for one hour in a muffle furnace and then austempered at 370 ^{0}C for one hour. The results are tabulated in table 3. Without any heat treatment the tensile strength was very low i.e. 714 N/mm^2. The elongation of samples was much higher i.e. 12.3%. The samples with the same composition were heated for one hour at temperature of 900 ^{0}C and then immersed in a salt bath at temperature 285 ^{0}C. The tensile strength was maximum i.e. 1657 N/mm^2. The elongation decreased to level of 3.2%. This was an amazing result. The other batch of samples with same composition was heated to 900 ^{0}C for one hour and then heated to higher austempering temperature i.e. 370 ^{0}C. Now the elongation was increased but the tensile strength decreased to 1154 N/mm^2. This experiment provides a choice for the design engineers to select the austempering temperature to get the desired properties. The engineers can get higher tensile strength with lower elongation or if they want higher elongation, they can choose lower austempering temperature.

In the present study, the ADI produced at austempering temperature 285 ^{0}C matched the Grade 5 of ASTM Standard i.e.

ASTM A897-90 with tensile strength of 1657 N/mm^2 against minimum tensile strength of 1600 N/mm^2 of the standard. The second batch of ADI produced at austemperature temperature 370 ^{0}C matched the Grade 2 of ASTM Standard with tensile strength of 1154 N/mm^2 against minimum tensile strength of 1050 N/mm^2 of the standard.

Similar results were found by other researchers, Prabhukumar Sellamuthu et al., heated the samples at two different austempering temperatures i.e. 300 ^{0}C and 360 ^{0}C. They found that the hardness and strength decreased with the rise of the austempering temperature [10]. Another researcher, M. Kaczorowski found that the ductility is increased when the austempering temperature was enhanced to 350 ^{0}C [3]. In present study the elongation was 3.2 % at austemperating temperature 285 ^{0}C but it was increased to 5.0 % when the temperature was increased to 370 ^{0}C.

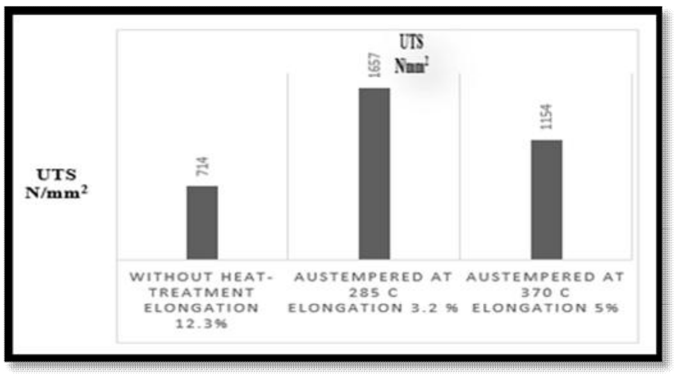

Figure 2. Results of austempering heat treatment of tensile test casting samples at low and high austempering temperatures.

The tensile strength results are represented graphically in figure 2. The maximum tensile strength was achieved when samples were austempered at lower heat treatment temperature i.e. 285 ^{0}C. The engineers can use the lower austempering temperature to get the maximum tensile strength with lower ductility. In case the design engineers require increased elongation, they can select higher austempering temperature.

V. CONCLUSION

1. The austempering process gave a choice to the engineers to increase the tensile strength by this process.
2. The tensile strength can be increased to double at lower austempering temperature e.g. 285 ^{0}C.
3. The process gave the choice to get the desired elongation. If engineers require higher elongation, they can select the higher austempering temperature.

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Causes of Delay in Lahore Orange Line Metro Train Project

Mahboob A. Chaudhry[1], Amir. M. Zafar[2], and Zahid A. Siddiqi[1], M. Aftab[3]

[1] Civil Engineering Department, The University of Lahore, Lahore, 54000, Pakistan
[2] Civil Engineering Department, The University of Lahore, Lahore, 54000, Pakistan
[3] Engineer

Corresponding author: Mahboob A. Chaudhry (e-mail: drmahboob@uol.edu.pk)

Abstract- During the last decade there is tremendous increase in the construction activities in Pakistan. Most of the development projects including orange line metro project are not completed within the allocated time and cost. It is necessary to identify the factors causing delay in such important projects. This study is carried out to establish the reasons due to which orange line metro project faced serious delays in its completion. For this purpose, a questionnaire consisting of 38 activities causing expected delays is prepared and distributed in all the eight zones of metro train transit project. Data collected from the sites has been processed, analyzed and results presented through bar charts. On the basis of the results it is observed that stay orders from the higher courts, late delivery of land by the client, frequent changes by the owner, non-payment of cash on time, late procurement of material at site and sudden cancellation of contract at package-2 are considered to be the most significant factors causing delays in orange line metro train project.

***Index Terms*-- Construction Projects, Delay Causes, Pakistan.**

I. INTRODUCTION

The Orange Line is an automated rapid convention system under construction in Lahore, and Pakistan's first modern rail-based mass rapid transit system.

A. ***Client:***

The project was launched in May 2014 with a memorandum signed between the Government of Pakistan and the Government of China. The Lahore Development Authority and the Government of Punjab are clients of the project.

B. ***Contractor:***

There were three main contractors working on this project, namely;

- **Habib Construction Services** was awarded a civil works package-1 worth Rs 21.49 billion in October 2015
- **ZKB Engineers and Constructors** for Civil Work (Package 2) between Chauburji and Ali Town at a cost of Rs.11.39 billion.
- **Sarwar Construction Company** was awarded (package 4) for civil works at Ali Town.

C. ***Consultant:***

Under a joint venture, the consultants of the **China Railways Engineering Consulting (CREC)** and the **National Engineering Services Pakistan (NESPAK)** started monitoring the structural work of the Orange Line Metro project. The consultancy cost of the project was Rs 2.4 billion.

D. ***Distribution of Work on Project:***

Project was distributed in 4 packages:
Package 1 starts from Dera Gujjran to Chauburgi (13.6km)
Package 2 is from Chauburgi to Ali town (13.5km)
Package 3 consists of depot located near Dera Gujran
Package 4 contains the yard located near Ali town

E. ***Track Length:***

The track length of Metro Train project is 27.1km. 25.4 km of the line is elevated (Fig 1.1), while 1.72 km is underground (Fig 1.2), and 0.7 km of track is laid in the transition zone between elevated and underground sections.

F. ***Rout Details:***

Orange line starts from Dera Gujran (G. T. Road) and terminats at Ali Town (Thokar Niaz Baig). It has 26 metro stations as shown in Fig-1.3

Figure 1.1: Structure of Orange Line Metro Train

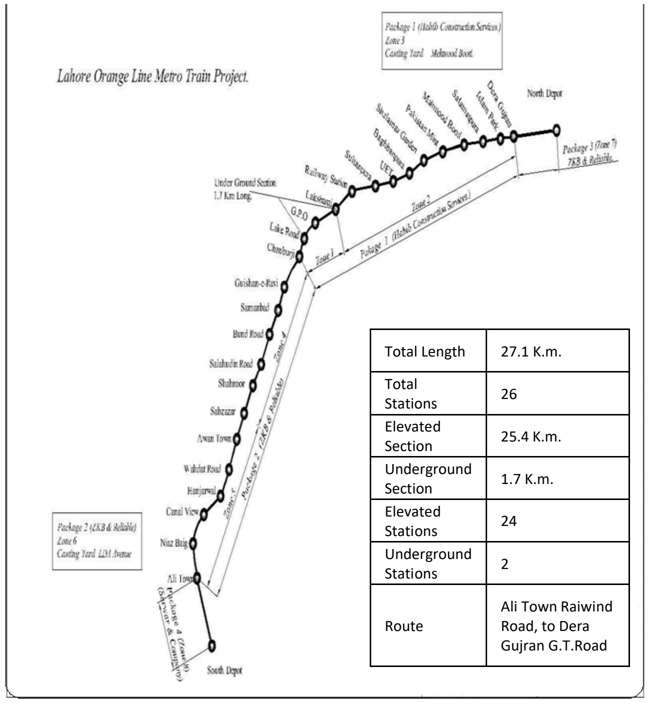
Figure 1.2: Underground Track

G. Start and Finish Time of Project:

Construction of the project began in October 2015. The deadline for completion of the project was December 25, 2017, but due to pendency of cases in the superior courts it was delayed. The Chinese government had also expressed concern over delay in the project,

H. Financer of Project:

Funding for the project was secured in December 2015 when the Exam Bank of China agreed to provide a soft loan of $ 1.60 billion for the project.



Total Length	27.1 K.m.
Total Stations	26
Elevated Section	25.4 K.m.
Underground Section	1.7 K.m.
Elevated Stations	24
Underground Stations	2
Route	Ali Town Raiwind Road, to Dera Gujran G.T.Road

Figure 1.3: Route Map of Orange Line Metro Train

I. Detail of Various Packages:

Package 1:

Habib Construction Services started working on Package 1. It consisted of three zones,

- **i. Zone1:** This zone was situated between Chuburgi and Lakshmi Chowk. Underground portion of Lahore Orange Line Metro Train Project was located in this zone.
- **ii. Zone 2:** This zone covered track from Lakshmi Chowk to Dera Gujran. This contained Elevated portion of track.
- **iii. Zone 3:** This zone was situated in Mehmood Booti. Casting yard of package 1 was located in this zone.

Package 2:

ZKB Engineering/Construction Company was working on Package 2. It covered three zones

- **i. Zone 4:** This zone was spread between Chuburgi to Sabzazar station. This consisted of Elevated portion of track.
- **ii. Zone 5:** This zone covered area between Sabzazar to Ali Town station. This is Elevated portion of track.
- **iii. Zone 6:** This zone is located in LDA Avenue. Casting yard of package 2 was located in this avenue.

Package 3 (Zone 7):
Package 3 contained depot located near Dera Gujran

Package 4 (Zone 8):
Package 4 contained depot located near Ali Town.

II. Literature Review

Luu Truong Van N.M [1] designed a theoretical model to know the attributes affecting the government sponsored projects. He developed a conceptual model of delay factors mostly related to law and administrative procedures. In the model they identified 28 delay factors, three of which were important factors that influenced the completion of the project. Those factors were information delays and lack of communication between the parties, incompetent owner and lack of competency of supervision consultant. The maximum delay depended upon the contractor and owner who had the main control upon the completion of project. S Shuja Safdar Gardezi [2] conducted a survey upon fifty projects through a questionnaire and information causing delay in construction industry were identified. There were 25 significant delay attributes from seven major groups of client, contractors, consultant, materials, labor, equipment, and contract related factors. The analysis showed that the most important factors were ten out of which top most factors were law and order situation, terrorism, inflation, design changes, lack of funds, payment delays and political influence. Mohammad Khoshgoftar [3] carried out a survey among the government sponsored projects to identify causes of delay in construction projects. The survey was conducted through questionnaire distributed to Iranian construction companies. The questionnaires were distributed to thirty clients, forty consultants and fifty-five contractors. The completed questionnaires were analyzed on the relative importance index method. The most important cause of delay in Iranian work were improper planning, site management, lack of communication between the parties, improper procurement of materials and change in orders etc. Ghulam Abbas Niazi [4] carried out survey in Afghanistan through questionnaire amongst sixty construction industries consisting of consultants, clients, and contractors. The collected data were analyzed through significance index method. Three major parties client, consultant and contractors were the main causes of delay. The important causes of delay were security, corruption, poor qualification of contractors, technical staff, poor site supervision and bureaucracy in government agencies. Adel Al-Kharashi [5] carried out a comprehensive survey in main seven groups of client, contractor, consultant, materials, suppliers, labor, contract and relationships. The survey was conducted for 86 clients, contractors and consultants involved in Saudi construction industry. The results showed that main causes of delay in construction industry were the lack of knowledge of respondents and dispute between consultants and contractors. The most important cause was absence of experienced persons involved in supply of manpower in the industry. The above research work showed that all countries had own-socio economics conditions and thus had their own reasons of delay in their construction activities.

This study is limited to Orange Line Metro Train project in Lahore; Pakistan, which was to be completed by joint venture of Pakistan & China. The causes of delay identified are not similar to the above-mentioned studies.

III. Data Collection

Data collection was spread over two phases. First phase was to collect data from 8 zones of the project. A specific questionnaire was proposed for gathering information from different zones. Questionnaire was firstly distributed on eight zones as pilot project. Information obtained was discussed with experienced personnel at site and their comments were included in the questionnaire. The final form of questionnaire (attached as annexure) was distributed at site and interviews were held with the site engineers and incharges of the zones. In total there were six questionnaires which were completed at each zone. Each questionnaire collected information regarding the delay factors of the followings:

1. Client,
2. Consultant,
3. Contractor,
4. Materials,
5. Equipments,
6. Miscellaneous.

The factors contained further details of activities in percentage of delay occurred at each zone mentioned under each factor. The reasons for delay were also mentioned therein.

The data was collected through final year students and the staff deputed for this purpose. During collection of the data our staff/students experienced various difficulties at site. Few were as under: -

i) The site staffs were reluctant to cooperate in giving correct information.
ii) Information required to be collected from files were difficult to be obtained.
iii) Mostly information obtained from contractor did not match with the one obtained from the client and the consultant.

The second phase was to analyze the collected data and draw bar charts for the activities of each factor mentioned above. Critical attributes were mentioned in the analysis and discussion upon the data was completed.

During collection of data six questionnaires were filled at each zone. Each factor further contains different activities which caused delay in each zone. The information collected from different zones were analyzed and bar charts prepared for all the factors. Data collected at each zone for all the six factors mentioned above with the detailed activities related to each factor i.e. (Client, Consultant, Contractor, Material, Equipment and Miscellaneous) was analyzed separately for each factor at each zone and thus 48 bar charts were prepared and analysis was done. The causes of delay in percentage were obtained.

IV. Analysis and Discussion on Collection of Data

In order to establish the factors affecting the efficiency of construction projects, the data collected against each activity from 8 zones is analyzed and average value calculated from bar charts drawn for this purpose.

Discussion on delay

Client

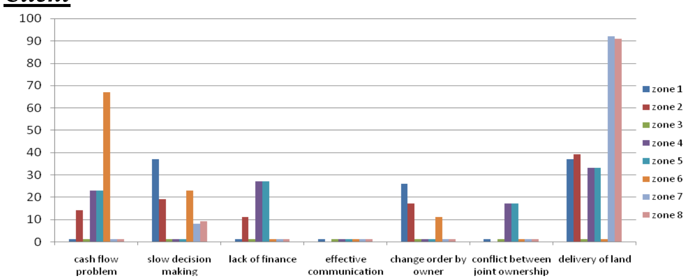


Figure 2.1: Client - Related Causes of Delay

From figure (2.1) it can be concluded that the factor which is considered most important is the late delivery (40.375%) of the land by the owner. The other factor causing delay are cash flow (15.5%) and slow decision making (12%) due to which the projects could not be completed in time. Several claims of extension in time period and change of orders made by the consultants and contractors against the decision of the client badly affected the progress of work. The client is supposed to make appropriate decision well in time as to avoid unnecessary delay in the completion of the project. Quick and good decision of the client will have positive effect on other ongoing projects of the client.

Consultant

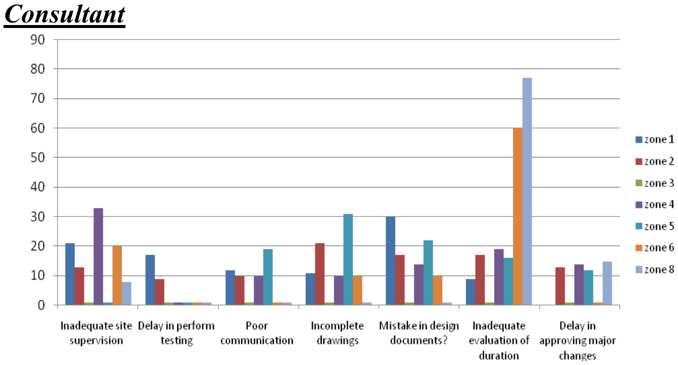


Figure 2.2: Consultant - Related Causes of Delay

From figure 2.2, it can be concluded that the factor which was considered most important was mainly inaccurate estimation of the completion period of the project (24.6%). Delay due to deficient site supervisory staff (12.125%) and faults in design documents (11.75%) were the other important factors. There are some delays which occurred due to manual errors can be easily avoided by deploying skilled and experienced work force.

Contractor

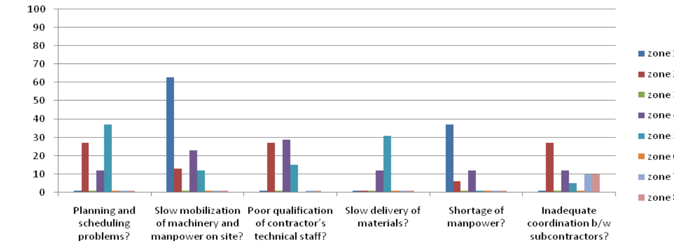


Figure 2.3: Contractor – Related Causes of Delay

From figure 2.3 it can be concluded that the factors which were considered most significant are slow mobilization of machinery and manpower on site (13.875%) and planning and scheduling problem (9.625%). The contractors should hire sub-contractors who are most experienced and having knowledge of work being assigned to them as their in-capabilities bring risk and bad name to the main contractors.

Material

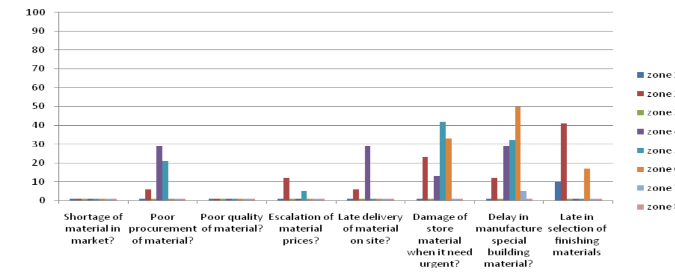


Figure 2.4: Material - Related Causes of Delay

From figure 2.4, it can be concluded that the factor which was considered to be the most important is in the case of the production of special type of building material at site (16.125%). Delays due to loss of stored material when it was needed urgently (13%) and late in selection of finishing material (8.5%) are considered to be equally important factors.

Equipment

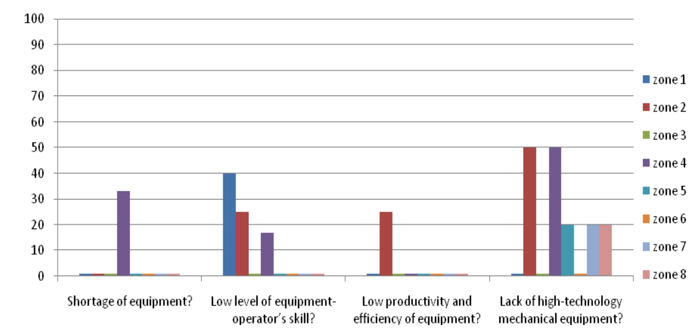


Figure 2.5: Equipment – Related Causes of Delay

From figure 2.5, it appears that lack of high technology mechanical equipment (20%) mostly affected the progress of work at site. Shortage of skilled employees (9.625%) and insufficient equipment (4.125%) have delayed the project work.

It is necessary to minimize such factor and to enhance incentives for the work force for in time completion of project.

Miscellaneous

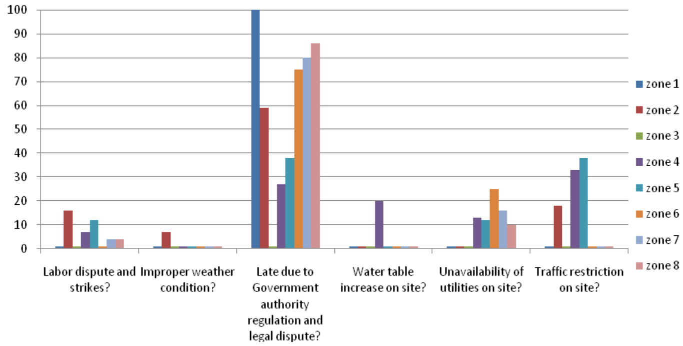


Figure 2.6: Miscellaneous Causes of Delay

From figure 2.6, it can be concluded that the factor considered to be the most important for diverse aspects is delay due to government authority regulations and legal dispute (57.875%). Delays due to traffic restrictions on the site (11.375%) and unavailability of utilities (8.375%) at site are not less important factors causing delay in the completion of work. Healthy working environment at site and encouraging incentives for the work force increase their productivity.

V. Discussion on Results & Conclusions

Following conclusions below are extracted from the results presented earlier for the owner, consultant and contractor.

Client

The client and their representatives played an important part in controlling the progress of current works and also projects of the near future. Their vision showed how important is their role in improving the construction performance. It is important that owner should deliver land to the contractor before execution of work. Delay in cash flow problem and slow decision making are most important factors that delay the project. Clients have higher expectations on contractors to complete the project. The client's responsibility is to check the works of contractor already completed, list of sub-contractors, necessary equipment and all-round performance at such construction projects.

Consultant

Consultant had major role in construction. It is important that consultant should have ability to analyze and overcome the future outcomes. They should have carried out proper evaluation of time duration of the construction project. The factors which were considered most significant are inadequate evaluation of project, delay due to inadequate site supervision and frequent revision in design documents. If consultant took appropriate measures then it could ensure high performance of work force

Contractor

Contractors have an important role in influencing the performance of construction projects. Contractors should have the experience of handling of similar projects, procurement of materials, trained manpower and necessary equipment required at site to avoid any delay in the progress of work. The contractor with their efficient performance accelerates the work and thus creates good working relationship with the client and its representatives. The factors that were considered most important are the slow mobilization of machinery, lack of manpower on site and the planning and scheduling problem.

Other factors that were considered to be most important are the delay in the production of specific building materials, delay due to the loss of stored material when required and late in selection of finishing materials.

Delays due to traffic restrictions on site, low productivity of labor and non-availability of various site utilities were seen as the most important factors. Contractors should pay attention to the list of subcontractors and keep a close watch on the work of subcontractors.

Out of miscellaneous factors that caused delay of the project, litigation and legal aspects were the most prominent. The causes of litigation were the presence of heritage sites near the project layout and under-capacity of the contractors to execute such large-scale projects.

VI. Recommendations

Following recommendations are made for the client, consultant and the contractor to improve the work efficiency. Also, recommendations for future work are presented at the end.

Client

Late delivery of land by owner:

Owner, mostly in the form of development authorities, need to expedite their efforts in land acquisition. All the relevant government departments are required to be taken on board so that disputes related to land acquisition would be nipped in the beginning.

Cash Flow Problem:

Funds act as a fuel to the construction project. Cash flow problems arise due to poor accounting procedures, delay in payments and mal-practices resulting in pilferage and wastage of funds. Therefore it is suggested that timely transparent and fluent supply of funds be ensured to avoid unnecessary delays.

Consultant

Inadequate evaluation of duration

Integrated project evaluation is required by keeping on board all the stakeholders from the beginning. Meticulous planning is required by the planning department.

Inadequate site supervision

Inadequate site supervision leads to uses of inferior materials and defects due to stupidity of workers. Experienced site supervisors should be deployed on site who should monitor all construction activities.

Mistakes in design documents

Design errors are inevitable as an important issue which has negative impact on the project and responsibilities should only be given to the experienced staff/firm in case of mega project.

- These documents should be checked and verified before finalization.
- Design which are done manually and with the help of software should be adequately vetted.
- Design responsibility should be given to the most experience staff/firm.
- Drawings should be scrutinized and reviewed carefully before finalization for construction.
- The issues of delays could have been minimized if there is good communication between consultant and client.

Contractor

Mobilization

Mobilization is a process in which machinery, labor, equipment, offices and other facilities are shifted to the work zone. Successful and efficient mobilization reflect the level of commitment of the contractor.

1. The contractor should set up construction facilities in orderly designated and approved work areas for all labor and equipment which is necessary to complete the work.
2. If utilities are available on this site, a contractor would be at ease with mobilization.

Planning and scheduling problems:

Most effort should be put in planning and scheduling of construction activities. It help the engineers to develop the logic of how the work is to be executed.

1. Planning could be done only after careful study of drawings. Hence, drawings should be delivered on site before start of project.

Slow Decision Making:

1. Non-technical leadership in the project is the root cause of slow decision making. More technical personal should be accommodated in the command structure so as to expedite the process of decision making.

2. Well-trained project planning professionals could be appointed so they sort out the problems before time or cost overrun.

Traffic disruption

Construction activities disturb and hinder the traffic flow. These recommendations would be helpful for upcoming projects.

1. Alternate/temporary routes should be defined for smooth flow of traffic.
2. Special safety staff and traffic wardens should be appointed on the route of project to make sure the smooth and safe flow of traffic.
3. Heavy traffic on the construction routes should only be allowed in low intensity hours
4. Vehicle parking should not be allowed on the routes where construction activities are being carried out.

Litigation and Legal Issues:

The contractors must try that the disputes are preferably resolved within the project team without litigation. The resulting delay during the legal proceedings can harm their reputation and profit.

Future Works

In future, development works can be improved:

- Increasing face to face interviews with the senior and experienced staff at site.
- Improving questionnaire by taking opinion of the professionals with different backgrounds of construction projects.
- Conducting more exhaustive case studies of other construction projects causing unnecessary delays.
- Broadening the range of factors causing delays in the construction projects.
- Framing integrated system for assessing the causes of delays in the ongoing infrastructure projects in Pakistan.

APPENDIX

QUESTIONNAIRE

Zone__________________ Date: _________________

Client:
Consultant:
Contractor:
Start time:_____________________Finish time: ____________
Sponsor:_______________________

Introduction:

A. Various cases of delay:

1. Client Related Delay Factors:

	Disagree (%)	Neutral	Agree (%)
Cash flow problem?			
Slow decision making?			
Lack of finance to complete the project?			
Effective communication and co-ordination between client and other parties?			
Change orders by owner during construction?			
Conflicts between joint-ownership of the project?			
Delivery of land to contractor on time?			

Reasons

Consultant Related Delay Factors:

	Disagree (%)	Neutral	Agree (%)
Inadequate site supervision by the consultant?			
Delay in perform testing by consultant?			
Poor communication and coordination between consultant and other parties?			
Incomplete drawings and late delivery of drawings on site?			
Mistake in design documents?			
Inadequate evaluation of project's duration?			
Delay in approving major changes in work?			

Reasons:

2. Contractor Related Delay Factors:

	Disagree (%)	Neutral	Agree (%)
Planning and scheduling problems?			
Slow mobilization of machinery and manpower on site?			
Poor qualification of contractor's technical staff?			
Slow delivery of materials?			
Shortage of manpower?			
Inadequate co-ordination b/w subcontractors?			

Reasons:

3. Material related delay factors:

	Disagree (%)	Neutral	Agree (%)
Shortage of material in market?			
Poor procurement of material?			
Poor quality of material?			
Escalation of material prices?			
Late delivery of material on site?			
Damage of store material when it needs urgent?			
Delay in manufacture special building material?			
Late in selection of finishing materials due to availability of many types in market?			

Reasons:

Equipment related delay factors:

	Disagree (%)	Neutral	Agree (%)
Shortage of equipment?			
Low level of equipment-operator's skill?			
Low productivity and efficiency of equipment?			
Lack of high-technology mechanical equipment?			

Reasons

2. **Miscellaneous**:

	Disagree (%)	Neutral	Agree (%)
Labor dispute and strikes?			
Improper weather condition?			
Late due to Government authority regulation and legal dispute?			
Water table increase on site?			
Unavailability of utilities on site?			
Traffic restriction on site?			

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It is to be mentioned further that this research work has been carried out purely for the sake of academic purposes and any of its content should not quoted or considered for any legal purpose.

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