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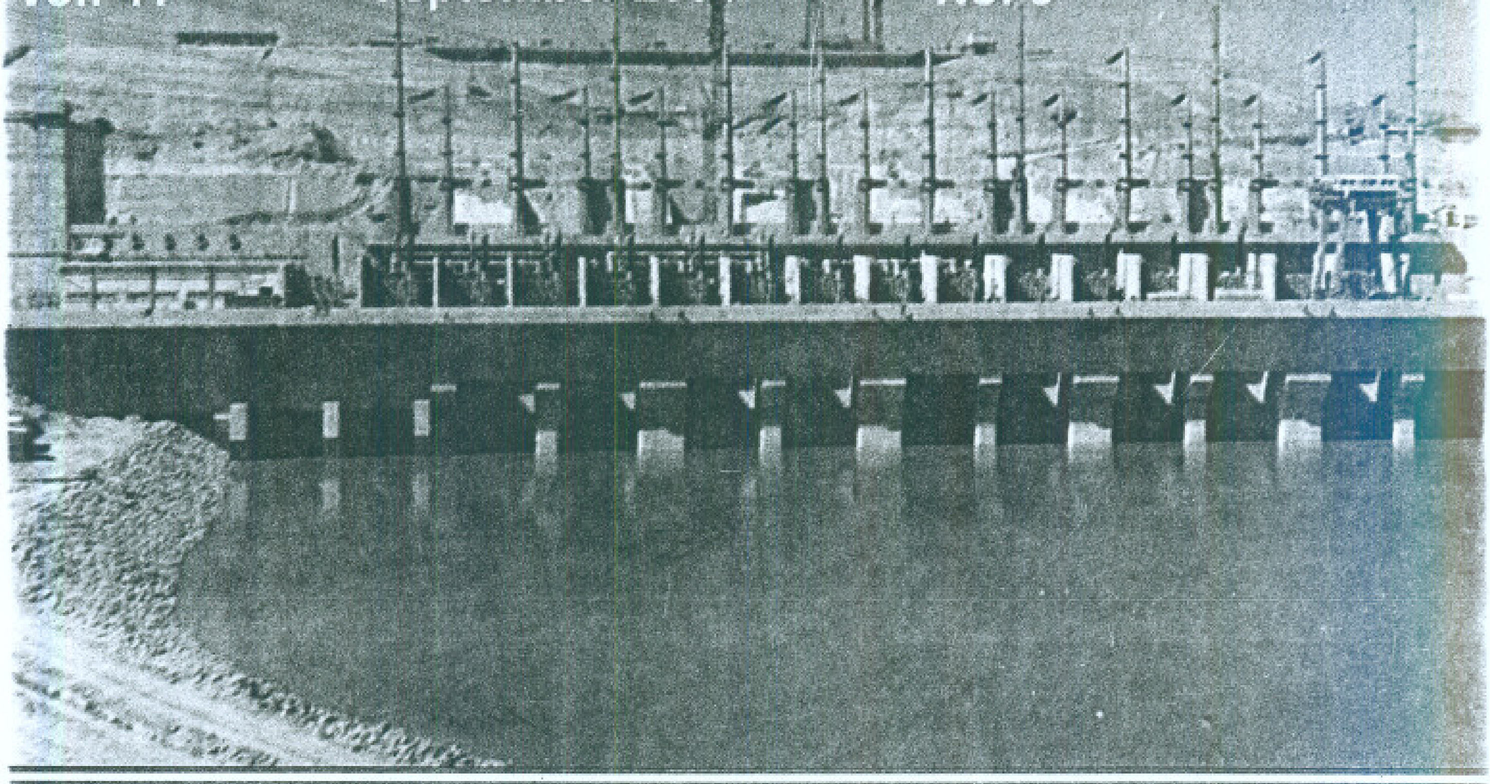

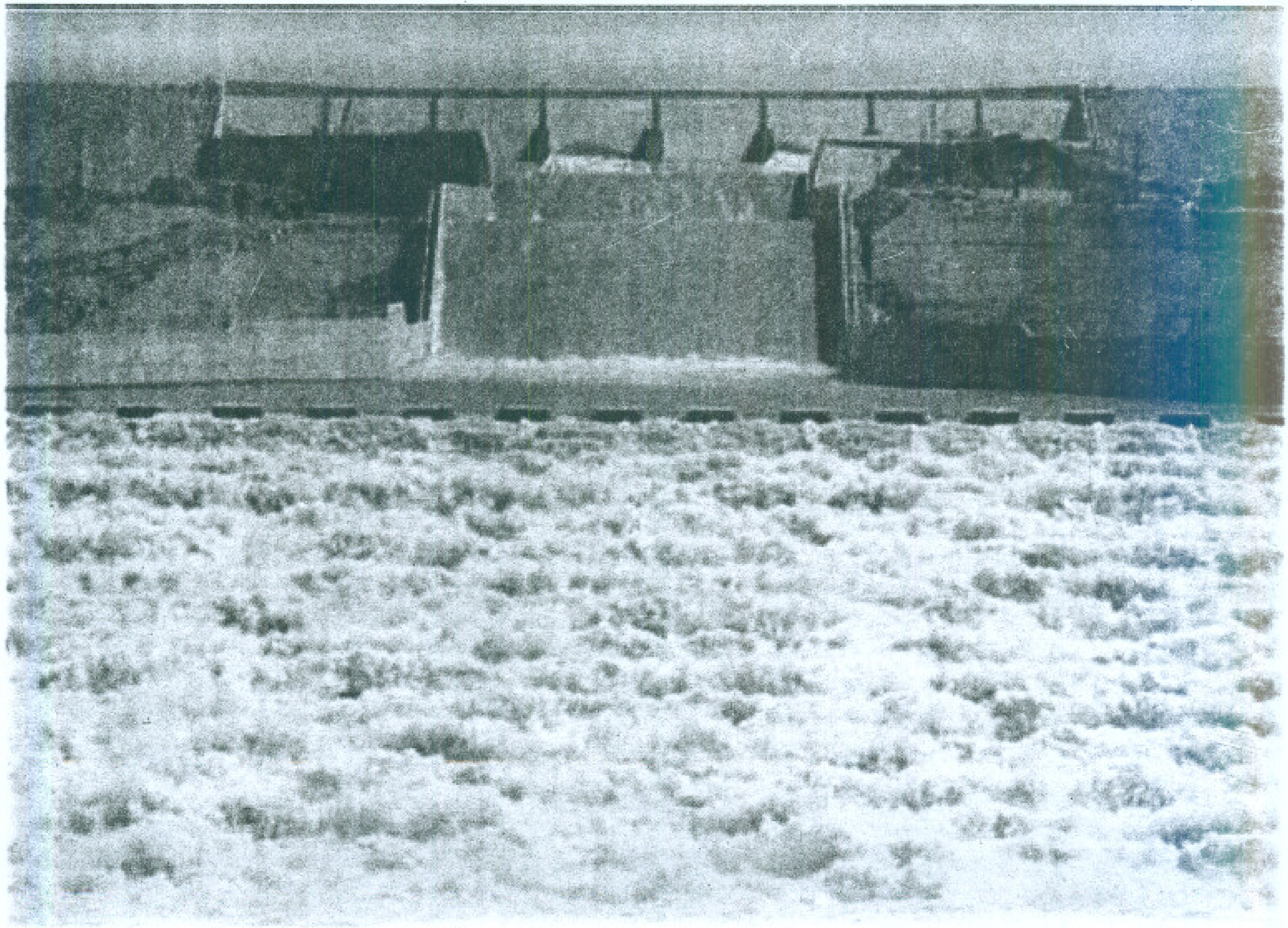

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COVER PHOTO

Upper Photo : Power House Ghazi Barotha Hydro – Power Project.

Bottom Photo : Spill – Way of Ghazi Barotha.

Photo and statement on the cover with the courtesy of **Engr. A. W. Mir.**

45th YEAR OF PUBLICATION

Engineering News

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NEWS

TECHNICAL VIEWS

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EDITORIAL

INEXPENSIVE POLLUTION FREE HYDROPOWER THE NEED OF THE DAY

The issue of the Engineering News Journal was going to the press when the Commissioning by the President of Pakistan of the First Hydel Power Unit of Ghazi Barotha Project on August 19, 2003 brought the happy and eventful news to the power stricken nation. When fully operative and supplemented with completion of quite a number of other small Hydel Power Projects in the Northern Areas the pollution free and substantially cheap electric energy will not only reduce the exorbitant thermal power tariff to the relief of domestic and commercial users but will also become a means of cost effective industrial and agriculture produce necessary for competitive exports in the scenario of World Trade Organization implementation after the year 2005.

International Power Companies operating thermal power units have been a subject of thorny discussion over the years for the supply of thermal power at exorbitantly inflated rates which tend to deter its use both by domestic and commercial users. It is high time further decisions are taken for construction of Kalabagh Dam which will provide huge Kilo-wattage of electric energy besides storage of water for irrigation use during scarcity of water availability in rabi season.

The posterity will for certain benefit from the positive decisions taken by the present generation. WAPDA in general and President of Pakistan in particular deserve gratitude of the public at large for their candid and calculated pronouncements for the construction of technically feasible and economically viable Kalabagh Dam along with Basha Diamer Dam and Akhori Dam Projects for which Feasibility Studies are in progress.

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WELCOME TO NEW MEMBERS

The Executive Council of the Pakistan Engineering Congress approved Membership of the following new members in to the Congress fold. The Engineering News congratulates all of them and welcomes to PEC Fold.

Members admitted on 23-8-2003

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PARAMETRIC STUDY OF HARD CHROME PLATING ON MILD STEEL

By

*** Prof. Dr. Taqi Zahid Butt and * Muhammad Umar Saeed**

Abstract

Hard Chrome Plating is the most recent important addition to the list of metals that can be practically electroplated. Hard Chrome Plating is produced by electrodeposition of Chromium from a solution containing chromic acid (CrO_3) and catalytic anion in proper proportion, which makes it different from the rest. The metal so produced is extremely hard and corrosion resistant.

*Due to its unique and distinguished method of electrodeposition its process control is quite difficult. Several factors can affect its characteristics. In this paper some of the physical parameters such as **Temperature, Current Density, Anode to Cathode Distance and Anode Area** leading towards and adequate deposit is discussed.*

Introduction

Electroplated chromium deposits rank among the most important plated metals and is used almost exclusively as the final deposit on parts [1]. With out the physical properties offered by electroplated chromium deposits, the service life of most parts would be much shorter due to wear, corrosion, and the like. Parts would have to be replaced or repaired more frequently, or they would have to be made from more expensive materials, thus wasting valuable resources.

The thickness of the chromium deposits falls into two classifications: decorative and functional. Decorative deposits are usually under 0.8μm in thickness. They offer a pleasing, reflective appearance while also providing corrosion resistance, lubricity, and durability.

Decorative chromium deposits are typically plated over nickel but are occasionally plated directly over the substrate of the part.

Functional or "Hard Chrome" deposits have a thickness customarily greater than 0.8μm and are used for industrial, not decorative, applications. In contrast to decorative deposits, functional chromium is usually plated directly over substrate.

The most common and the oldest commercial type of chromium process utilize hexavalent chromium (Cr^{+6}) in an aqueous solution containing one or more catalysts.

Early in 1970s aqueous trivalent chromium (Cr^{+3}) solution started to attain commercial success for the decorative applications. Even though much work has been done functional trivalent chromium deposits, there are only restricted numbers of application due to limitations in the physical properties of thick deposits.

Metallurgy & Materials Science Division: Faculty of Engineering & Technology, University of the Punjab, Quaid-e-Azam Campus (New Campus), Lahore, PAKISTAN

Noteworthy improvements in hexavalent chromium plating came with the introduction of double and organic catalyzed systems. Double catalyzed (mixed-catalyst) system introduced in 1949 generally contain sulfate and silicofluoride in forms that are either self-regulating or operator regulated. In comparison to the initial commercial processes that were only sulfate catalyzed, double catalyzed processes offer higher plating speeds and help activate the part prior to plating by mildly etching the substrate. Fluoride compounds with limited solubility supply the free fluoride catalyst in self-regulating processes. Undissolved fluoride compounds stayed in the bath until they dissolved to increase the concentration of free fluoride. Operator regulated bath depends upon the proper additions of free fluorides from outside the tank.

Organic catalyzed processes have increased plating speeds and the improved deposit physical properties, and they do not etch iron substrates. Proprietary organic additives are added from outside the tank to maintain the proper concentration. This process is well suited for the functional application.

Experimental

Experimental work was done in following four stages.

(1) Pretreatment (2) Plating (3) Post-treatment (4) Testing

1. Pretreatment

Mild Steel specimens were finely ground, polished and Buffed until they were free from any sort of scratches. Their weight and Area were calculated accurately. First they were boiled in a 10 % NaOH solution for 20 minutes to remove grease. After washing with running tap water they were dipped in a 30 % H_2SO_4 solution for 1-2 minutes. Again washed with running tap water. For perfect adherence they were etched in Chromic acid solution (25 g/L) using a reverse current of $25 A/dm^2$ & 4V for 3-5 minutes. [2,3,5]

2. Plating

After pretreatment, Mild Steel specimens were dipped in the plating solution i.e. 250 g/L Chromic Acid & 2.5 g/L Sulphuric Acid with Chromic Acid : Catalyst Ratio = 100:1 in a plating tank maintained at 52-55 °C using lead-tin alloy anode at a current density of $25 A/dm^2$ & 4-5 V for 2 hrs. This procedure was repeated for different values of Temperature, Current Density, Anode Area and Anode-Cathode Distance. But changing one variable at a time and keeping others constant. [2,5]

3. Post-treatment

After plating MS specimens were again washed in running tap water ang Buffed to obtain luster. [2,4]

4. Testing

MS specimens were reweighed and difference in weight was calculated and so is thickness of plating using the following formula: [5]

$$T = \frac{10^4 \ W\,(gm)}{A\,(cm^2) \times D} \quad \text{(micron)}$$

Where W = weight gained

A = Area plated

D = Density of Cr in g/cm^3

Results & Discussion

Results

Following tables give information about the effect of

- Temperature on the Thickness of Plating
- Current Density on the Thickness of Plating
- Anode-Cathode Distance on the Thickness of Plating
- Anode Area on the Thickness of Plating
- Current Density on the Current Efficiency
- Current Density on the Plating Speed

Following Parameters remain same for all experiments

Solution = 250g/L Chromic Acid

Chromic Acid : Catalyst Ratio = 100:1

Density of Cr = D = 7.19 gm/cm^3

Time = t = 2 hr

Voltage = V = 5.5-6.5 V

Cathode Area = 48 cm^2

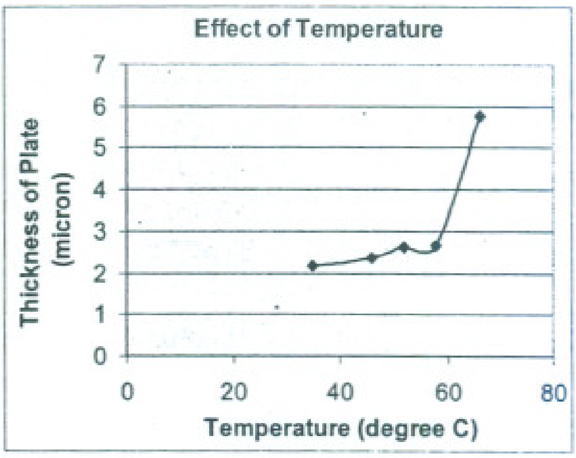
Effect of Temperature

Anode-Cathode Distance = 4 inch

Anode Area = 43.8872 cm^2

Current Density = 13.28 A/dm^2

No. Of Obs.	Temperature T, *°C*	Thickness of Plate $=10^4 W/DA$, *micron*
01	35	2.182
02	46	2.363
03	52	2.611
04	58	2.670



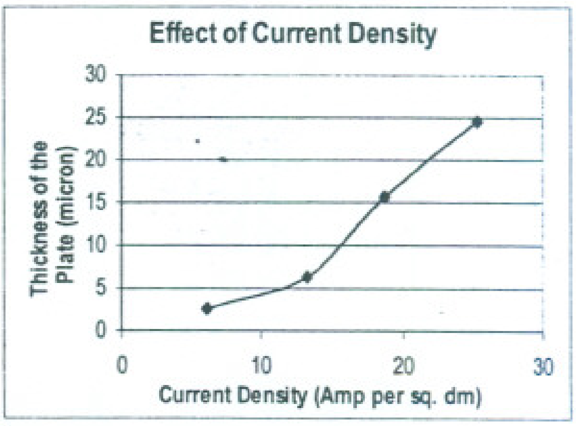
Effect of Current Density

Anode-Cathode Distance = 4 inch

Temperature = T = 52 °C

Anode Area = 43.8872 cm^2

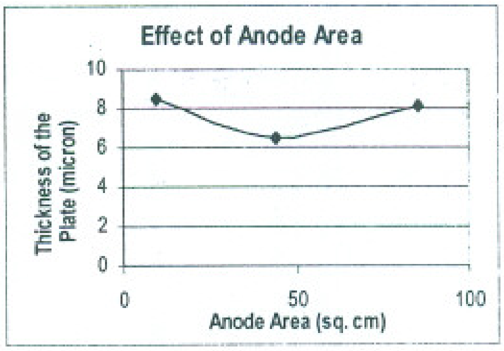
No. of Obs.	Current Density *Amp/dm²*	Thickness of Plate $= 10^4 W/DA$, *micron*
01	6.10	2.611
02	13.28	6.2911
03	18.75	15.588
04	25.25	24.458



Effect of Anode Area

Temperature = T = 52 °C
Anode-Cathode Distance = 4 inch
Current Density = 13.28 A/dm^2

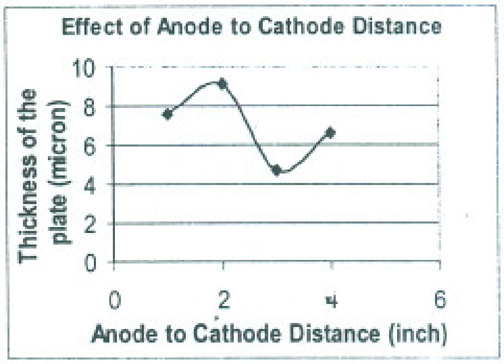
No. Of Obs.	Anode Area *cm^2*	Thickness of Plate =10^4W/DA, *micron*
01	9.7527	8.431
02	43.8872	6.517
03	85.3361	8.051



Effect of Anode-Cathode Distance

Temperature = T = 52 °C
Anode Area = 43.8872 cm^2
Current Density = 13.28 A/dm^2

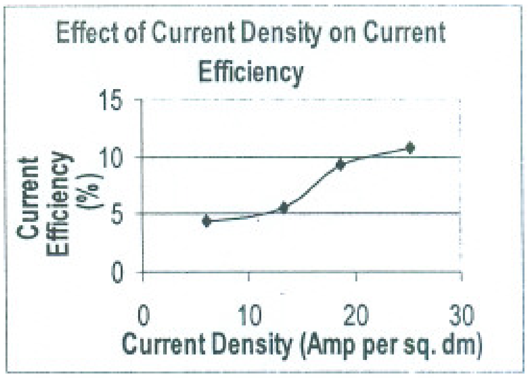
No. Of Obs.	Anode-Cath. Distance, *Inches*	Thickness of Plate=10^4W/DA, *micron*
01	01	7.599
02	02	9.1212
03	03	4.6610
04	04	6.5700



Effect of Current Density on Current Efficiency

Temperature = T = 52 °C
Anode-Cathode Distance = 4 inch
Anode Area = 43.8872 cm^2

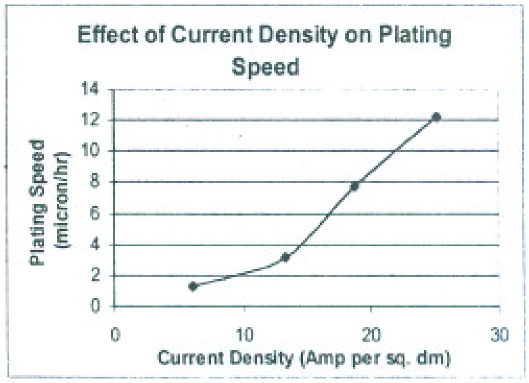
No. of Obs.	Current Density *Amp/dm^2*	Current Efficiency = W*100/It*0.323, %
01	6.10	4.41
02	13.28	5.51
03	18.75	9.25
04	25.25	10.78



Effect of Current Density on Plating Speed

Temperature = T = 52 °C
Anode-Cathode Distance = 4 inch
Anode Area = 43.8872 cm^2

No. of Obs.	Current Density *Amp/dm^2*	Plating Speed = 10^4W/DAT, *micron/hr*
01	6.10	1.305
02	13.28	3.145
03	18.75	7.794
04	25.25	12.229



Discussion

As expected, increase in Temperature and Current Density increases the Plating thickness exponentially but only up to a certain limit beyond that burning of deposit start. [1] On the other hand below that Plating thickness or coated film would be too weak and small which is useless by any means. Also Plating Speed is a linear function of Current Density. i.e. higher Current Density leads to quicker deposits. But the Current Efficiency first increases rapidly with increase in Temperature and Current Density up to that limit, beyond that it decreases or becomes nearly constant with further increase in temperature and Current Density. So at higher Temperature and Current Density a large amount of current is wasted and is not used in building up thick Plating. Hence there lies an optimum range for Temperature and Current Density. Ideally and from industrial point of view for a 50 % Current Efficiency, 15-30 A/dm^2 Current Density & 45-55 °C Temperature should be employed.

Anode-Cathode distance & Anode-Area are two newly observed effects which are not given much importance during plating. But they have large effect on properties of Electrodeposits.

Anode-Cathode distance is a different parameter from those stated above. Although it has no pronounced effect on thickness but an important one in controlling the Plating conditions and Deposit characteristic. In Hard Chrome Plating, the closer the Anode-Cathode distance the better the deposit distribution. But this distance less than 4" cause a fluctuation in Current Density and so is deposit characteristics. This effect touches the extreme if the distance is reduced further. Thus for a better & steady control on Current Density distance above 4" should be employed.

Anode-Area has also lesser effect on Plating Thickness rather on properties. Anode-Area directly effect corrosion rate or we can say plating speed or plating efficiency. Plating is difficult to control with lesser Anode-Area. As connections are disconnected due to excessive corrosion and variation in Current Density occurs too. For better deposit Anode should be slightly longer than Cathodes.

References

1. Schlesinger, M. and Paunovic, M., *Modern Electroplating*, 4th edition, John Wiley & Sons, Inc. 2000.

2. Canning, *Handbook on Electroplating, 22nd edition,* W. Canning Ltd, 1978.

3. Blum, W. and Hogaboom, G. B., *Principles of Electroplating and Electroforming*, 2nd edition, McGraw-Hill Book Company, 1930.

4. Graham, A. K., *Electroplating Engineering HandBook*, 3rd edition, Van Nostrand Reinhold Company,1988.

5. Metals HandBook Vol. 5, *Source Cleaning, Finishing and Coating,* 9th edition, A. S. T. M, 1985.

Determination of Medium Voltage Cables Parameters using LCR Measurements

By

Dr. Suhail Aftab Qureshi* and Ghulam. Murtaza Hashmi**

1. Abstract

Resistance, inductance, capacitance, and characteristic impedance of a cable play an important role in determining the behaviour of a cable under investigation. These characteristics are denoted by cable parameters. LCR measurements have been taken using LCR meter. The cable parameters have been determined for different modes of propagation, and their frequency dependency is also studied. The length and the modal series impedance matrix of the test cable are determined, and are compared with those, determined by TDR measurements [1]. In this paper, three phase Medium Voltage (MV) Mass Impregnated Paper (MIP) Cable, 15 KV, having termination on both ends, and three core MV cross linked polyethylene (XLPE) cable, 24KV, are investigated.

2. Introduction

Resistance, inductance, capacitance, and characteristic impedance of a cable play an important role in determining the behaviour of a cable under investigation, and are denoted by cable parameters. Cable parameters can be easily determined by taking LCR measurements with the help of LCR meter. The available instrument in the High Voltage Laboratory of Kungl Tekniska Högskolan (KTH) is HEWLETT PACKARD Precision LCR Meter of Serial No. 4284A, having frequency range of 20 Hz up to 1 MHz for high frequency measurements. Connections for different modes of propagation of test cables are made with LCR meter for open and short circuiting of the far end (with respect to LCR meter) of the cable with sheath. When the far end of the test cable is kept opened (not short circuited with the sheath as per connection in the close end), LCR meter measures parallel parameters, i.e. parallel Resistance R_p and parallel capacitance C_p, conductance G, and susceptance B of the test cable. When the far end of the test cable is short circuited with sheath as per connection in the close end of the test cable, LCR meter measures series parameters, i.e. series resistance R_s and series inductance L_s of the test cable. Let Z01 is the characteristic impedance when only L_s and C_p are taken into consideration and Z02 is the characteristic mpedance when in addition to L_s and C_p, R_s, G, and B are also taken into account. Therefore Z01 is an approximation and is given by [2, 3]:

$$Z01 = \sqrt{\frac{L_s}{C_p}}$$

Z02 includes the effect of resistance of the cable and is given by its absolute value

$$Z02 = \left|\sqrt{\frac{R_s + j\omega L_s}{G + jB}}\right|$$

LCR measurements are made for the following two types of test cables:

1. Three phase MIP cable
2. Three phase XLPE cable

by making following types of connections for different mode of propagation, as have already been done for TDR measurements [1]:

* **Electrical Engineering Department University of Engineering and Technology (UET) Lahore -Pakistan.

Connection No.1: All three conductors are connected together and connected to sheath through LCR meter, i.e. three phase to sheath mode of propagation.

Connection No.2: Conductor 1 is connected to sheath through LCR meter, i.e. single phase to sheath mode of propagation.

Connection No.3: Conductor 1 and 2 are connected through LCR meter, i.e. phase to phase mode of propagation.

Connection No.4: Conductor 1 and 2 are connected through LCR meter, conductor 2 is connected to sheath, i.e. phase to phase mode of propagation with phase 2 connected to sheath.

3. Three Phase MIP Cable

The test cable is connected to LCR meter by making following connections.

3.1 Connection No.1

This connection is shown in Fig. 1. The LCR measurements for both, far end open circuited and short circuited with sheath as per connection in the close end, for the connection of Fig. 1 are given in Table 1.

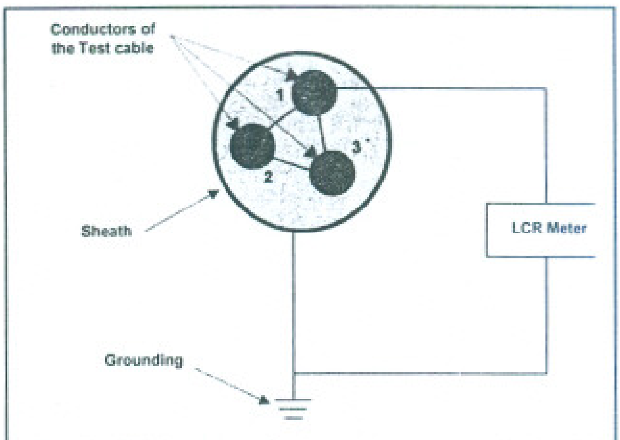


Fig. 1: *All three conductors are connected together and connected to sheath through LCR Meter*

Characteristic impedance is frequency dependent. The dependency of Z01 and Z02 on frequency for connection No.1 is shown in Fig. 2.

From the Fig. 2, it is clear that Z01 and Z02 vary with frequency, and become approximately equal in the frequency range above 10 KHz. Before reaching this frequency, both vary with different proportions by increasing frequency.

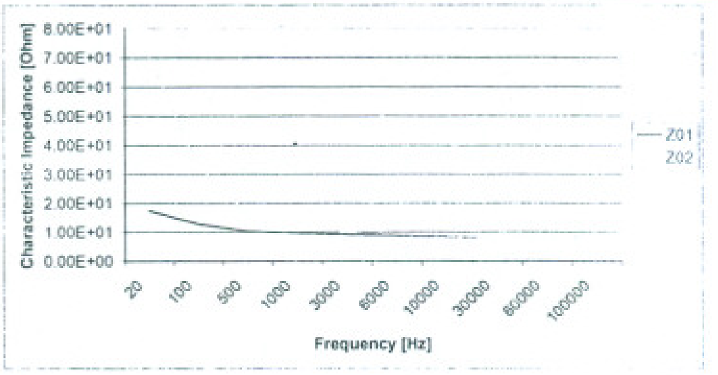


Fig. 2: *Dependency of characteristic impedance of MIP cable on frequency for connection No.1*

3.2 Connection No.2

This connection is shown in Fig. 3. The LCR measurements for both, far end open circuited and short circuited with sheath as per connection in the close end, for the connection of Fig. 3 are given in Table. 2.

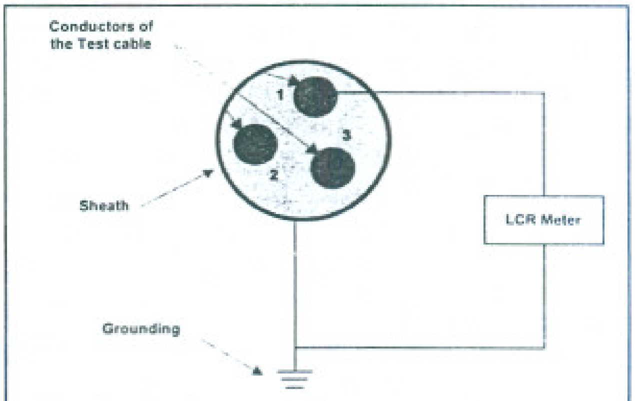


Fig. 3: *Conductor 1 is connected to sheath through LCR Meter*

Characteristic impedance is frequency dependent. The dependency of Z01 and Z02 on frequency for connection No.2 is shown in Fig. 4.

From the Fig. 4, it is clear that Z01 and Z02 become approximately equal in the frequency range above 30 KHz.

3.3 Connection No. 3

This connection is shown in Fig. 5. The LCR measurements for both, far end open circuited and short circuited with sheath as per connection in the close end, for the connection of Fig. 5 are given in Table. 3.

Characteristic impedance is frequency dependent. The dependency of Z01 and Z02 on frequency for connection No.3 is shown in Fig. 6. From the Fig. 6, it is clear that Z01 and Z02 become approximately equal at the frequency of 100 KHz.

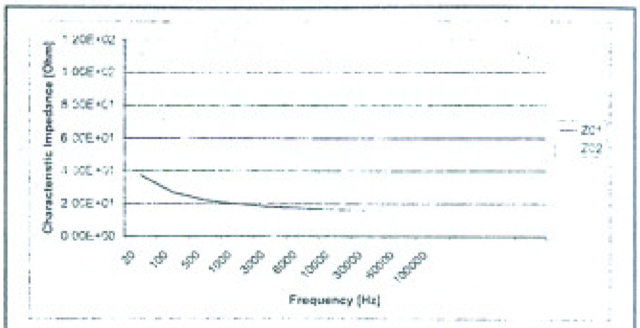


Fig. 4: *Dependency of characteristic impedance of MIP cable on frequency for connection No.2*

3.4 Connection No.4

This connection is shown in Fig. 7. The LCR measurements for both, far end open circuited and short circuited with sheath as per connection in the close end, for the connection of Fig. 7 are given in Table. 4.

Characteristic impedance is frequency dependent. The dependency of Z01 and Z02 on frequency for connection No.4 is shown in Fig. 8.

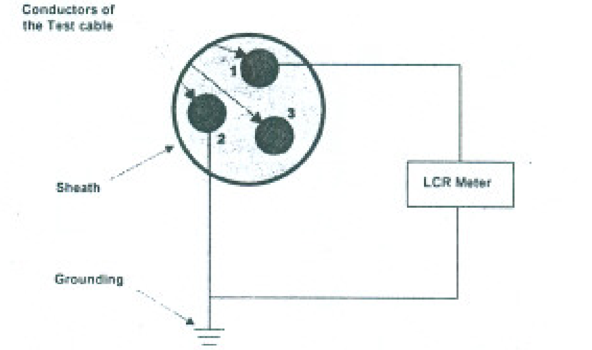


Fig. 5: *Conductor 1 and 2 are connected through LCR Meter*

4. Determination of Modal Series Impedance Matrix of Three Phase MIP Cable using LCR Measurements

Using LCR measurements, it is possible to determine the series impedance matrix of three phase mass impregnated paper cable. The selected frequency for this calculation is 100 KHz, because at this frequency Z01 and Z02 become approximately equal. The approximate value of characteristic impedance, i.e. Z01 will be used.

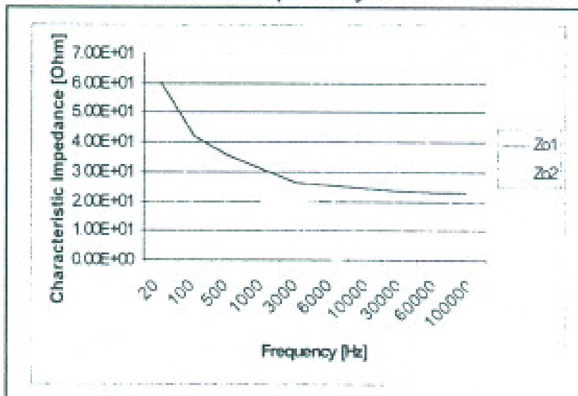


Fig. 6: *Dependency of characteristic impedance of MIP cable on frequency for connection No.3*

4.1 Self Impedance of Conductor No.1

For determination of self impedance of conductor 1, the connection is made between conductor 1 and sheath as shown in connection No.2 in Fig. 3.

From Tab. 2:

$Z_{11} = Z_{01}$ = Characteristic impedance of the cable for single phase to sheath connection (taking approximate value).

$Z_{11} = 15.80\Omega$

From Fig. 3 [1]

$Z_{11} = Z_s$ = Self characteristic impedance of conductor 1, and

$$Z_{11} = \frac{U_1}{I_1} = \frac{U}{I} = Z_0 = 15.80\Omega$$

$$Z_s = Z_{11} = 15.80\Omega$$

4.2 Mutual Impedance of Conductors 1 and 2

For determination of mutual impedance, the connection is made between conductor 1 and 2 with conductor 2 is connected to sheath as shown in Connection No.4 in Fig. 7.

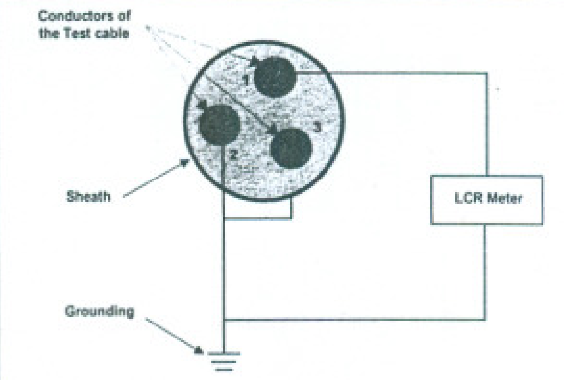


Fig. 7: *Conductor 1 and 2 are connected through LCR Meter and conductor No. 2 is connected to sheath*

From Tab. 4.

$$Z_0 = Z_{01} = 14.51\Omega$$

From Fig. 7[1]

$Z_{11} = Z_s$ = Self characteristic impedance of conductor 1

$Z_{12} = Z_m$ = Mutual characteristic impedance of conductor 1 & 2

$$Z_m^2 = Z_s^2 - Z_s Z_0$$

$$Z_m = \sqrt{Z_s^2 - Z_s Z_0}$$

$$Z_m = \sqrt{(15.80)^2 - (15.80)(14.51)}$$

$$Z_m = \sqrt{249.64 - 229.258}$$

$$Z_m = 4.51\Omega$$

$$Z_s + 2Z_m = 15.80 + 2(4.51) = 24.82\Omega$$

$$Z_s - Z_m = 15.80 - 4.51 = 11.29\Omega$$

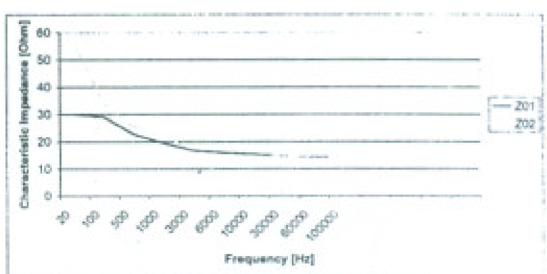


Fig. 8: *Dependency of characteristic impedance of MIP cable on frequency for connection No.4*

Hence

$$Z_{mode-MIP-LCR} = \begin{bmatrix} Z_s + 2Z_m & 0 & 0 \\ 0 & Z_s - Z_m & 0 \\ 0 & 0 & Z_s - Z_m \end{bmatrix}$$

$$= \begin{bmatrix} 24.82 & 0 & 0 \\ 0 & 11.29 & 0 \\ 0 & 0 & 11.29 \end{bmatrix}$$

is the Modal Series Impedance Matrix of MIP Cable calculated by LCR measurements. It is interesting to note that the entities of modal series impedance matrix calculated above by LCR measurements are not equal to that of modal series impedance matrix calculated by TDR measurements [1]. The factor $Z_s - Z_m$ is in the same range in both matrices, but $Z_s + 2Z_m$ differs by a multiplying factor of 2 in modal series impedance matrix. In principle, the entities of both matrices should be the same. One possible reason for this deviation could be the different frequencies for two methods at which measurements have been taken. In TDR method, 10 ns pulse is used for which fundamental frequency is 50 MHz [4], but in case of LCR method, measurements are taken at the frequency of 100 KHz.

5. Measurement of the Length of the MIP Cable

The MIP cable is wounded on the cable drum, so it is not possible to measure the correct length physically unless laying down it on the flat floor. LCR measurement method has been used for the measurement of its length. In principle, if the capacitance per unit length of the test cable C_1 is known, the length can be calculated by dividing the total capacitance of the test cable, C_t by C_1.

Mathematically, $l = \frac{C_t}{C_1}$

Where l is the length of the test cable in meters. The capacitance of the cable can be determined by LCR measurements. The cable is connected through LCR meter as shown in Fig. 3, i.e. conductor 1 is connected to the sheath through LCR meter. First, the capacitance of a sample of the test cable. i.e. 1.4m long is measured at a frequency spectrum ranging from 20Hz up to 100 KHz for determination of C_1. Secondly, the capacitance of the test cable C_t is measured for the same frequency spectrum. An overview of the capacitances of the sample and that of test cable is shown in Tab. 5, for some specific frequencies in the frequency spectrum.

The calculated length of the test cable is drawn versus frequency in Fig. 9. From the Fig. 9, it is clear that the estimated length of the test cable approximately remains constant at lower and medium frequencies, but at higher frequencies.ie. at 60 KHz, it increases with the increase in frequency. In principle, at higher frequencies, the lumped parameters of the cable are not sustained more and are changed to distributed parameters. For that, the results regarding calculation of the length of the cable using LCR method becomes invalid because the measured capacitance of the test cable is not correct at higher frequencies. This fact is shown in Fig. 9, where the length deviates from its constant value at higher frequencies.

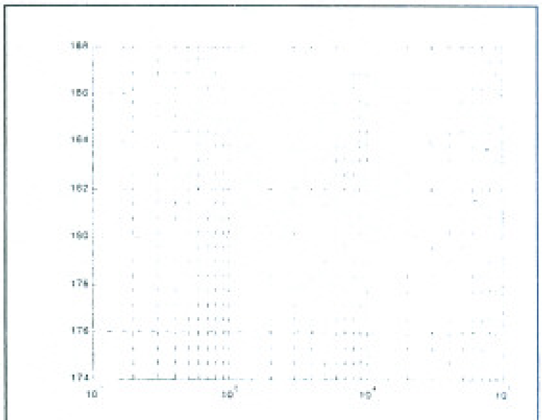


Fig. 9: *Deviation of the estimated length of MIP cable with frequency due to inaccurate measured* ..

Practically it is recommended to take into account the line parameters of the cable at lower frequencies. As the length of the test cable remains approximately constant at lower frequencies, so the length of MIP cable is, l = 174m. The length measured by TDR measurements [1] is 174.5m, so the results of both methods match with each other [5]. In case of TDR method, three phase to sheath mode of propagation in taken into account, while in case of LCR method, single phase to sheath mode is considered for the measurement of the length of cable, but the results are the same. This proves the fact, that any mode of propagation can be considered for the measurement of the length of the test cable.

6. Three Phase XLPE Cable

The three phase XLPE cable is connected to LCR meter by making the same connections as did for MIP cable in previous Section No.3 [4]. The cable parameters have been determined for different modes of propagation [4].

7. Comparison of Characteristic Impedance of MIP and XLPE Cables for Different Connections

The characteristic impedances of MIP and XLPE cable for different connections have been calculated using LCR measurements in Section No.3 and 6 respectively [4]. It will be of interest to compare these values of two types of test cables. This comparison is shown in Tab. 6 at a frequency of 0.1MHz

It is clear from the above table that XLPE cable has higher characteristic impedance than mass impregnated paper cable for all kind of connections.

8. Conclusions

1. It is possible to determine the cable parameters (R, L, C, G, & B) and characteristic impedance of MIP and XLPE cables using LCR measurements..

2. For MIP cable, modal series impedance matrix entities calculated by LCR measurements are not equal to those calculated by TDR measurements.

3. The length of MIP cable can be determined by LCR measurements, and is the same as determined by TDR measurements.

4. The length of MIP cable can be determined from the measurements taken for any mode of propagation.

5. At higher frequencies, the lumped parameters of the cables are not sustained more and are changed to distributed parameters. Therefore line parameters of the cables are taken into account at lower frequencies.

6. XLPE cable has higher characteristic impedance than MIP cable for all kind of connections.

9. References

[1] G. Murtaza Hashmi, Dr. Suhail Aftab Qureshi, "Measurement of Time Domain Reflectometry to Determine Different Characteristics of Three Phase Medium Voltage Mass Impregnated Paper Cable" *University of Engineering and Technology (UET),* Lahore-Paksitan, May, 2002.

[2] I. Froroth, "Methods for High Frequency Analysis of Electrical Power Distribution Networks", Vattenfall and Electric Power Research Centre, EKC, KTH, Stockholm, Sweden

[3] W. L. Weeks, Yi Min Diao, "Wave Propagation Characteristics in Underground Power Cables", *IEEE Transaction on Power Apparatus and Systems*", October 1984.

[4] G. Murtaza Hashmi "Determination of Propagation Constants of Three Phase Medium Voltage Cables using Time Domain Reflectometry " Masters Thesis Work, at the *Royal Institute of Technology, (KTH),* Stockholm, Sweden, February, 2001.

[5] G. Mugala, "High Frequency Properties of High Voltage Distribution Cables , State of the Art report, *Kungle Tekniska Hogskolan,* Stockholm, Sweden.

F(Hz)	Rp(ohm)	Cp(F)	G(S)	B(S)
20	1.22E+07	1.76E-07	8.21E-08	2.21E-05
100	1.68E+06	1.75E-07	5.94E-07	1.10E-04
500	2.18E+05	1.74E-07	4.58E-06	5.48E-04
1000	8.95E+04	1.74E-07	1.12E-05	1.09E-03
3000	2.18E+04	1.72E-07	4.59E-05	3.25E-03
6000	9.04E+03	1.71E-07	1.10E-04	6.46E-03
10000	4.74E+03	1.70E-07	2.10E-04	1.07E-02
30000	1.12E+03	1.71E-07	8.91E-04	3.22E-02
60000	3.67E+02	1.78E-07	2.72E-03	6.69E-02
100000	117.053	2.00E-07	8.49E-03	1.25E-01

F(Hz)	Rs(ohm)	Ls(H)	Z01	Z02
20	0.11	5.33E-05	17.45	70.82
100	0.12	2.86E-05	12.83	33.06
500	0.13	1.86E-05	10.37	16.22
1000	0.14	1.65E-05	9.75	12.67
3000	0.17	1.44E-05	9.14	9.95
6000	0.23	1.32E-05	8.78	9.17
10000	0.27	1.23E-05	8.51	8.74
30000	0.45	1.13E-05	8.13	8.21
60000	0.79	1.15E-05	8.03	8.10
100000	1.66	1.36E-05	8.24	8.31

Tab. 1: *Dependency of cable parameters of MIP cable on frequency for connection No.1*

F(Hz)	Rp(ohm)	Cp(F)	G(S)	B(S)
20	2.64E+07	8.43E-08	3.84E-08	1.06E-05
100	3.57E+06	8.39E-08	2.75E-07	5.27E-05
500	4.59E+05	8.34E-08	2.18E-06	2.62E-04
1000	1.87E+05	8.31E-08	5.32E-06	5.22E-04
3000	4.58E+04	8.24E-08	2.17E-05	1.55E-03
6000	1.97E+04	8.19E-08	5.22E-05	3.09E-03
10000	1.01E+04	8.16E-08	9.90E-05	5.13E-03
30000	2.42E+03	8.16E-08	4.11E-04	1.54E-02
60000	8.15E+02	8.49E-08	1.21E-03	3.19E-02
100000	270.458	9.55E-08	3.59E-03	5.96E-02

F(Hz)	Rs(ohm)	Ls(H)	Z01	Z02
20	0.13153	1.18E-04	37.42	111.79
100	0.14379	6.01E-05	26.81	53.10
500	0.18263	4.10E-05	22.28	29.21
1000	0.21514	3.33E-05	20.06	23.98
3000	0.27941	2.67E-05	18.07	19.24
6000	0.35615	2.43E-05	17.23	17.83
10000	0.4413	2.28E-05	16.76	17.10
30000	0.75643	2.08E-05	16.07	16.11
60000	1.2729	2.10E-05	15.78	15.82
100000	2.45495	2.38E-05	15.86	15.92

Tab. 2: *Dependency of cable parameters of MIP cable on frequency for connection No.2*

F(Hz)	Rp(ohm)	Cp(F)	G(S)	B(S)
20	4.97E+07	5.31E-08	2.07E-08	6.67E-06
100	6.01E+06	5.29E-08	1.64E-07	3.32E-05
500	7.54E+05	5.25E-08	1.32E-06	1.65E-04
1000	3.06E+05	5.24E-08	3.26E-06	3.29E-04
3000	7.43E+04	5.20E-08	1.34E-05	9.80E-04
6000	3.10E+04	5.17E-08	3.21E-05	1.95E-03
10000	1.64E+04	5.14E-08	6.09E-05	3.23E-03
30000	4.02E+03	5.14E-08	2.49E-04	9.70E-03
60000	1.40E+03	5.34E-08	7.06E-04	2.01E-02
100000	494.165	5.98E-08	2.02E-03	3.76E-02

F(Hz)	Rs(ohm)	Ls(H)	Z01	Z02
20	0.06379	1.92E-04	60.12	43.83
100	0.07668	9.38E-05	42.15	24.21
500	0.15524	6.65E-05	35.61	29.54
1000	0.22393	4.97E-05	30.83	19.80
3000	0.32087	3.62E-05	26.45	19.66
6000	0.41275	3.28E-05	25.20	20.09
10000	0.51564	3.08E-05	24.56	14.37
30000	0.88181	2.83E-05	23.52	16.40
60000	1.42013	2.84E-05	23.11	16.94
100000	2.48817	3.12E-05	22.90	22.91

Tab. 3: *Dependency of cable parameters of MIP cable on frequency for connection No.3*

F(Hz)	Rp(ohm)	Cp(F)	G(S)	B(S)
20	2.33E+07	8.83E-08	3.88E-08	1.11E-05
100	3.43E+06	8.80E-08	2.91E-07	5.53E-05
500	4.38E+05	8.74E-08	2.28E-06	2.75E-04
1000	1.80E+05	8.71E-08	5.58E-06	5.47E-04
3000	4.39E+04	8.64E-08	2.28E-05	1.63E-03
6000	1.83E+04	8.59E-08	5.47E-05	3.24E-03
10000	9.65E+03	8.55E-08	1.04E-04	5.37E-03
30000	2.33E+03	8.56E-08	4.29E-04	1.61E-02
60000	7.96E+02	8.92E-08	1.26E-03	3.36E-02
100000	2.64E+02	1.01E-07	3.79E-03	6.34E-02

F(Hz)	Rs(ohm)	Ls(H)	Z01	Z02
20	0.03438	7.96E-05	30.02	56.80
100	0.04304	7.42E-05	29.05	33.89
500	0.11346	4.55E-05	22.82	25.79
1000	0.15581	3.27E-05	19.38	21.71
3000	0.21682	2.42E-05	16.74	17.61
6000	0.28189	2.19E-05	15.97	16.42
10000	0.35471	2.06E-05	15.51	15.80
30000	0.61715	1.88E-05	14.84	14.95
60000	1.02751	1.89E-05	14.58	14.65
100000	1.91505	2.12E-05	14.51	14.57

Tab. 4: *Dependency of cable parameters for MIP cable on frequency for connection No.4*

Frequency (Hz)	Capacitance of the sample (nF)	Capacitance of sample/m; C_1 (nF)	Capacitance of test cable; C_t (nF)	Calculated length of test cable; $l = \frac{C_t}{C_1}$ (m)
100	0.6748	0.4820	83.92	174.09
500	0.6698	0.4784	83.37	174.27
10000	0.6536	0.4668	81.57	174.73
60000	0.6356	0.4540	84.88	186.94

Tab. 5: *LCR method for the measurement of the length of MIP cable*

Type of Connection	MIP Cable		XLPE Cable	
	Z01 (Ohm)	Z02 (Ohm)	Z01 (Ohm)	Z02 (Ohm)
1	8.24	8.31	12.78	12.83
2	15.80	15.92	33.00	33.06
3	23.00	23.00	59.60	59.70
4	14.51	14.57	33.30	33.38

Tab. 6: *Comparison of characteristic impedances of MIP and XLPE cables for different connections using LCR measurements*

OBITUARIES

May their souls rest in Peace

1. Engr. Zia-ullah Awan
   Chief Engineer WAPDA
2. Engr. Muzaffar Ali Shah
   Additional Secretary (Retd.)
   Govt. of the Punjab
3. Engr. Capt. (R) Muhammad Zahoor
   XEN Irrigation Department, Punjab
4. Engr. Sheikh Mahmood Amjad
   XEN Irrigation Department, Punjab
5. Mr. M. Javed Akhtar
   Deputy Secretary PEC
6. Syed Nazar Hussain
   Security Guard PEC

A BRIEF ANALYSIS OF MONENCO'S RANKING STUDIES AND THE VISION 2025 WATER AND POWER DEVELOPMENT PROGRAMME

By

Engr. Altaf-ur-Rahman*

MONENCO, a Canadian Consulting firm engaged by WAPDA in 1981-1983 to carry out studies for possible hydroelectric generation and storage schemes on Indus and its tributaries. The studies lacked the modern facilities of GPS and satellite imagery and requires to be updated. The main omission are the Indus river between Tarbela and Dasu and ignominy the Vast Plain around Jaglot close to Gilgit confluence with Indus. These are discussed in the following :

Monenco carried out the Ranking Studies for possible Storage and Hydroelectric Projects on Rivers Indus, Jhelum and Tributaries in 1981-1983 in three (3) Volumes and recommended that Basha is the most siuitable after Kalabagh. They also carried out detailed Pre-feasibility Study of Basha in 11 Volumes. The location Plan of the Storage and Hydroelectric studies is at Exhibit-1 and Profile of Indus River from Kalabagh to ceasefire line is at Exhibit-2 and 3 while Exhibit-4 gives their Ranking of schemes on Indus River.

Exhibit-2 shows that the first scheme up-stream of Tarbela is at Thakot i.e. a gap of 138 Km is unutilized. While the Bunji Scheme and other schemes listed in Exhibit-4 were dealt only by desk work and no apparent work in field.

It is a great step by WAPDA to institute these schemes to feasibility stage including Basha Project. The main hurdle in implementation is the upgrading of KKH.

Monenco did the planning in early eighties and except for a brief review, no detailed work was done subsequently.

GTZ did remarkable work in identifying and planning to pre-feasibility such projects as Allai Khawar, Khan Khawar, Dubair Khawar and Golangol which have now been taken up. They also setup GPS network in Northern areas and did estimate hydrology parameters for Northern areas streams. Further review of the schemes is required. Upstream of Tarbela, there are three valleys which can develop storages i.e. at Chilas, Skardu on Indus River and Yugo on Shigar River. It is quite obvious that Basha Site should fully expoit the Chilas valley as Skardu has environmental implication and Yugo is a rather remote site, or least for present.

Downstream of Basha, Monenco Ranking places Dasu as most favourable but its ranking position depends on Basha being in place first.

---

* Consultant WAPDA

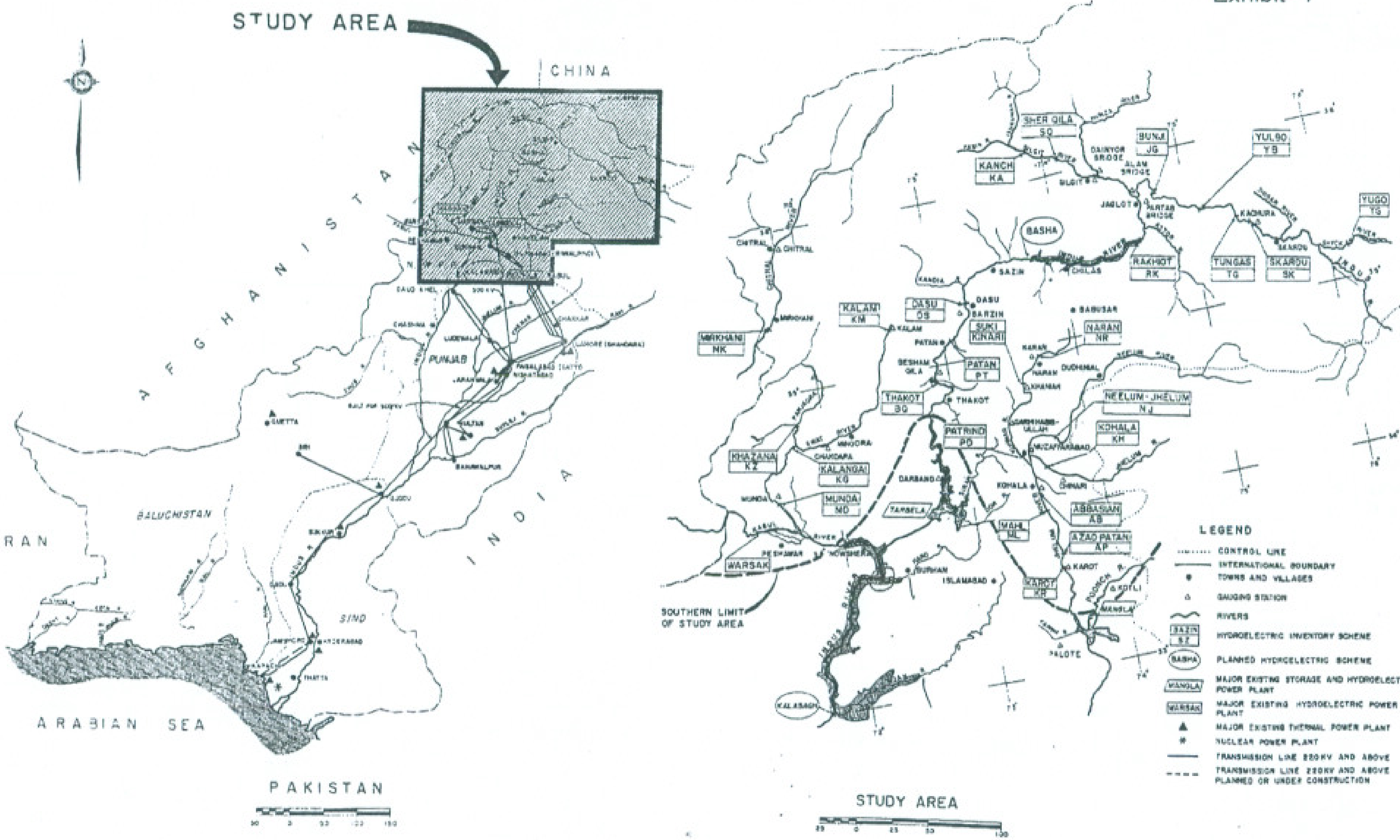
The great Horse Shoe loop (47 Km) of Indus River up-stream of Basha Reservoir near Bunji has attracted the planners as well as Monenco. Although the ranking is after Dasu (By Monenco), they have said that more studies are required to assess the site's capability. With a diversion dam of 210 m and the head across the tunnel of 200 m, a 1290 MW Power Generation was proposed. The present undertaken Pre-feasibility study has proposed a hydropower output of 4630 MW as also the tunnel length has been shortened to 8 Km by choosing a better alignment. This puts the Bunji Project at the top of all the hydroelectric schemes and even on the top of Tarbela.

The great omission in the Monenco Studies, has been ignoring the Vast Plain around Juglot at confluence of Gilgit and Indus. Preliminary examination resulted in proposing a reservoir of about 5 MAF and Power Generation of 3600 MW Exhibit-5. This encroaches the Bunji Tunnel capability somewhat but total generation will be around 6500 MW on combining the two schemes. Even the reservoir of 5 MAF would justify taking up the study to Feasibility Level what to say of the cheap power generation @ 2.3 cents/Kw 11 right to Kot Lakhput Grid.

There are only minor environmental implications and the benefits of this scheme are enormous. The cheap generation with no environmental effect will steady the Tariff, which is so far going up and up without any sign of being steady or reduction, making the life miserable for all. The Northern areas can have subsidized Tariff rates and can be developed to produce nuts like Pistachio, Almonds and Pecans in addition to Potatoes, Peaches, Apples and Apricots. In addition the improvement of KKH will enhance the Tourism several times.

Recommendations and Findings are that the 1980's studies by Canadians (Monenco) suffered lack of deep insight due to the access difficulties and the presently available sophistication of GPS and Satellite imageries. Revision of studies by Monenco can be taken up to exploit the capability of Indus River and it is possible to steady the Power Tariff.

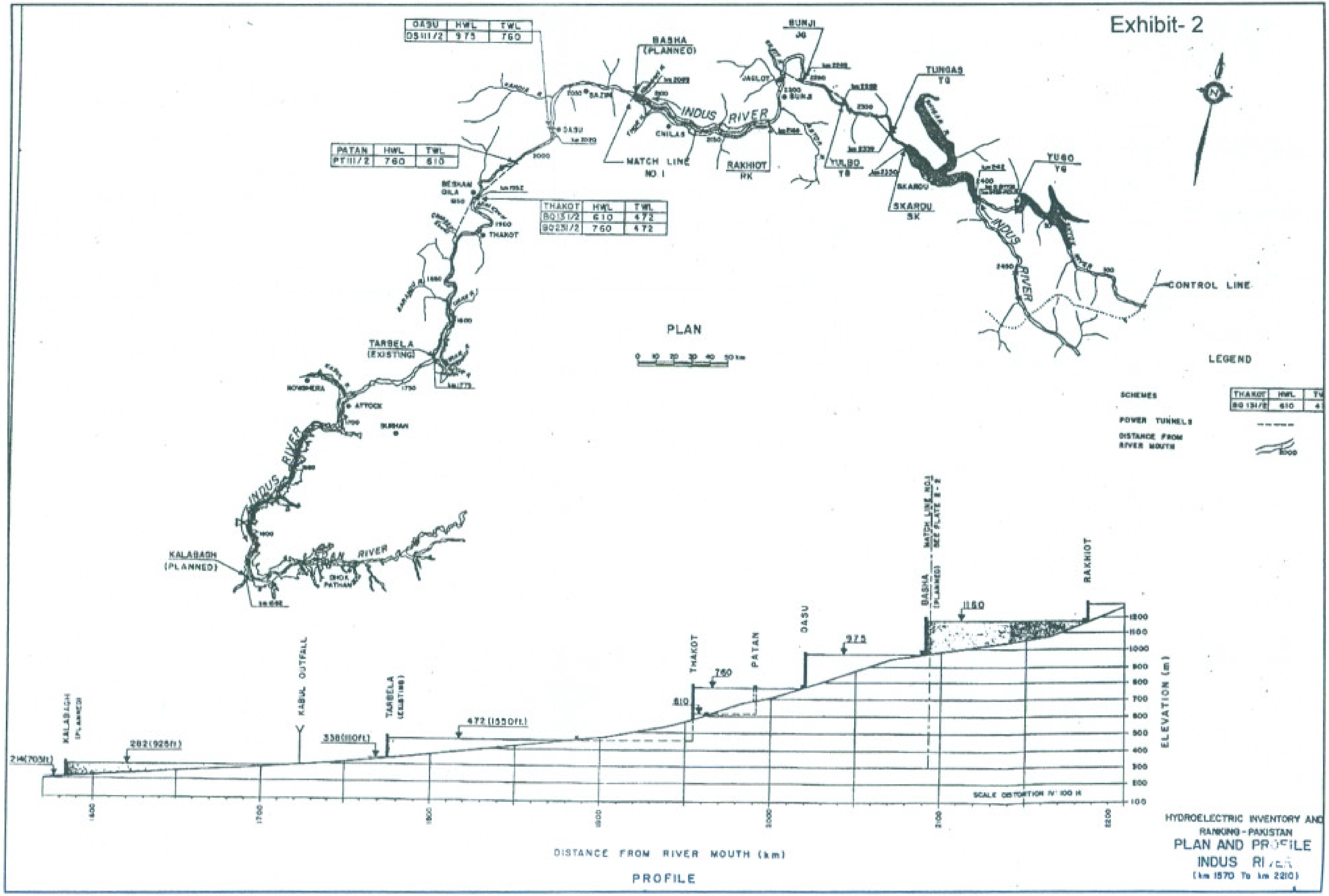
Exhibit- 1



HYDROELECTRIC INVENTORY AND RANKING - PAKISTAN

PAKISTAN AND RIVER BASIN MAPS

Exhibit- 2



PLAN
INDUS RIVER
KALABAGH (PLANNED)
TARBELA (EXISTING)
BESHAM QILA
THAKOT
PATAN
DASU
BASHA (PLANNED)
MATCH LINE NO. I
CHILAS
RAKHIOT RK
BUNJI JG
YULBO YB
TUNGAS TG
SKARDU SK
YUGO YG
CONTROL LINE
ATTOCK
NOWSHERA
DHOK PATHAN
LEGEND
SCHEMES
POWER TUNNELS
DISTANCE FROM RIVER MOUTH
DASU | HWL | TWL
DS111/2 | 975 | 760
PATAN | HWL | TWL
PT111/2 | 760 | 610
THAKOT | HWL | TWL
BQ131/2 | 610 | 472
BQ231/2 | 760 | 472
PROFILE
DISTANCE FROM RIVER MOUTH (km)
ELEVATION (m)
KABUL OUTFALL
214(703ft)
282(925ft)
338(1110ft)
472(1550ft)
610
760
975
1160
SCALE DISTORTION IV: 100 H
HYDROELECTRIC INVENTORY AND RANKING - PAKISTAN
PLAN AND PROFILE
INDUS RIVER
(km 1570 To km 2210)

Exhibit- 3

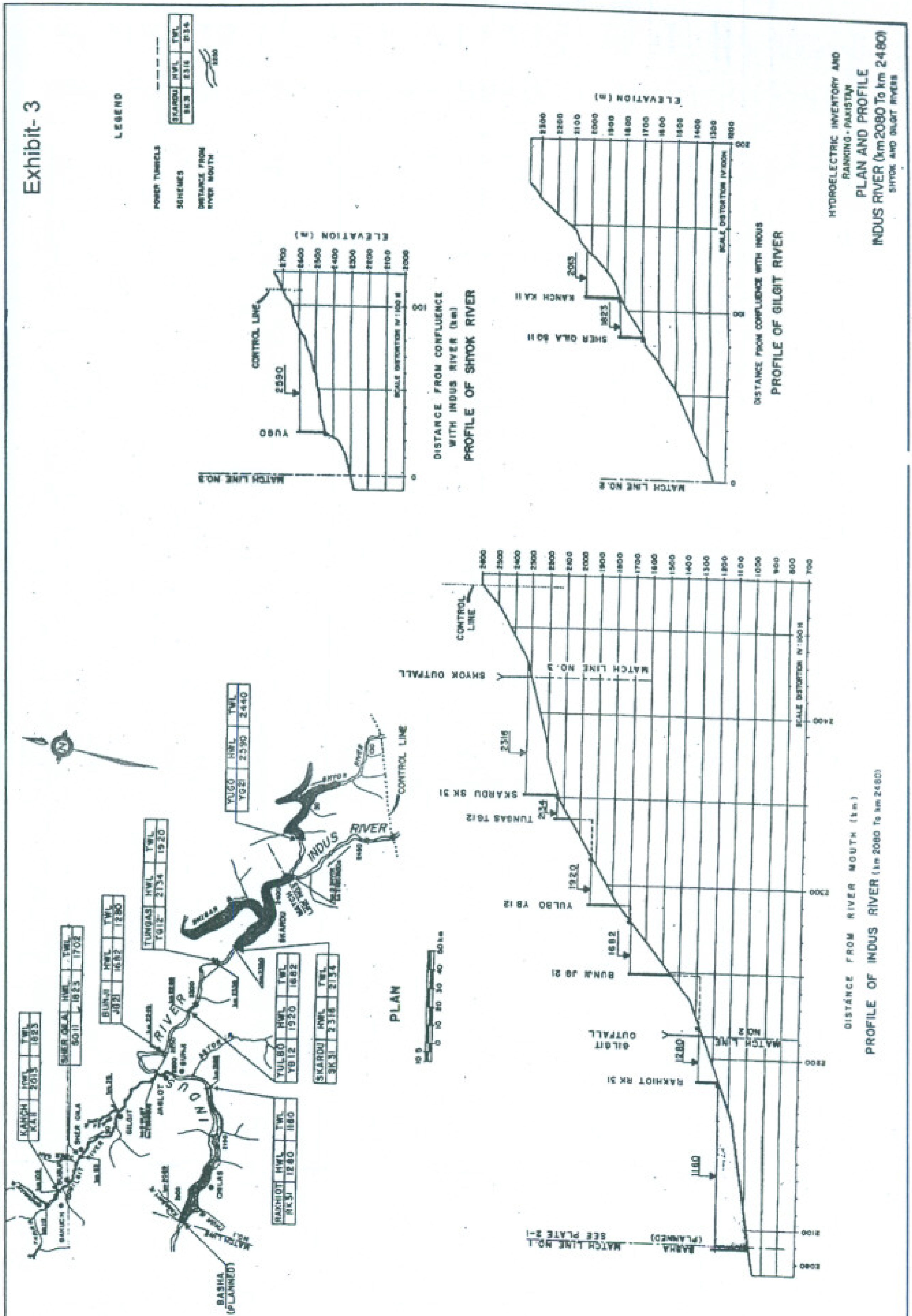
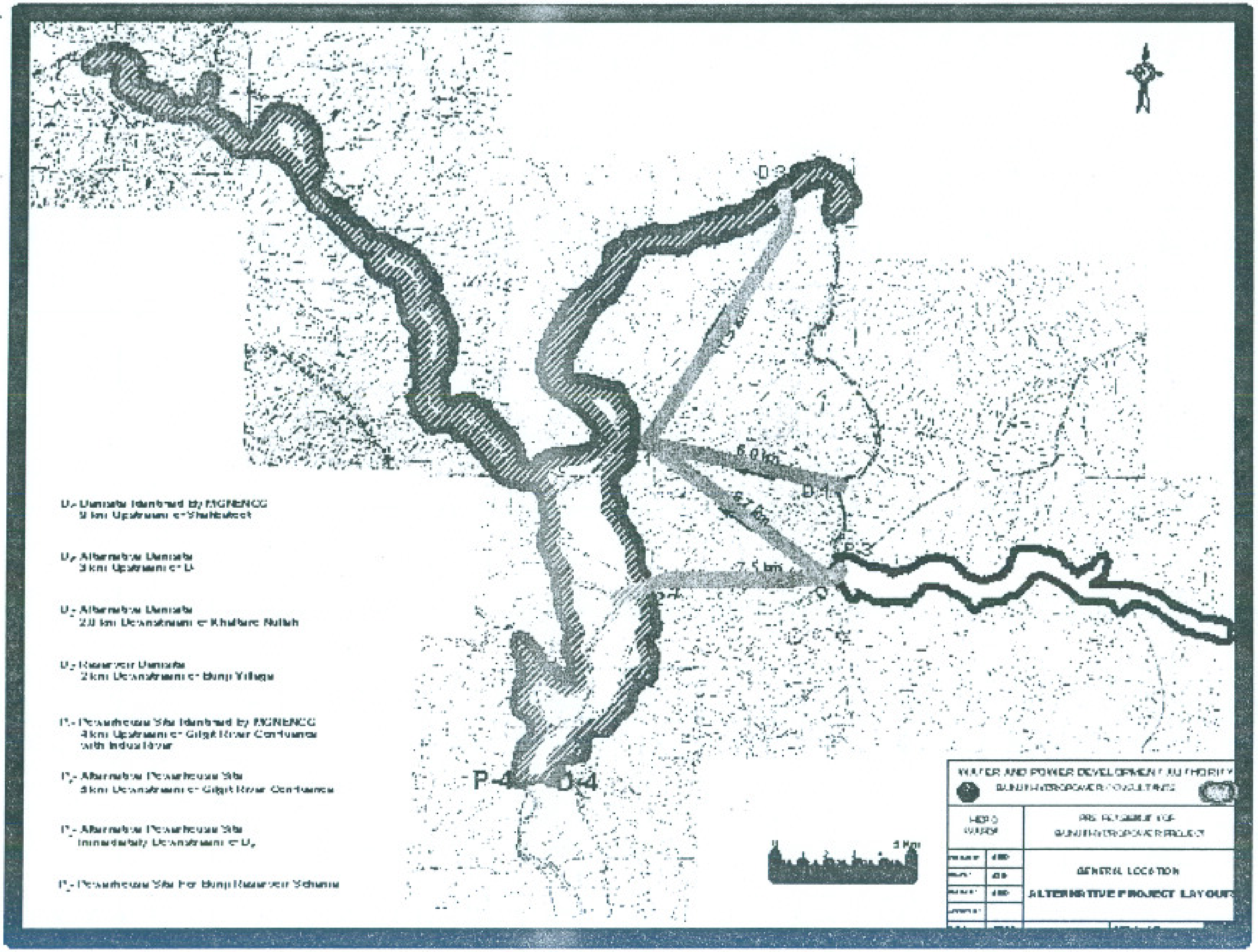

LEGEND
POWER TUNNELS
SCHEMES
DISTANCE FROM RIVER MOUTH
PLAN
INDUS RIVER
CONTROL LINE
BASHA (PLANNED)
PROFILE OF SHYOK RIVER
PROFILE OF GILGIT RIVER
DISTANCE FROM RIVER MOUTH (km)
PROFILE OF INDUS RIVER (km 2080 To km 2480)
HYDROELECTRIC INVENTORY AND RANKING - PAKISTAN
PLAN AND PROFILE
INDUS RIVER (km2080 To km 2480)
SHYOK AND GILGIT RIVERS

TABLE 2-1
INVENTORY OF SCHEMES - INDUS RIVER BASIN

REFERENCE DATA								PHYSICAL CHARACTERISTICS										POWER AND COST DATA										REMARK
Item	Scheme	River	Alternative	Revision	Purpose Power-P Storages-S	Drawing Reference	Text Reference	Approx. Distance from Mouth	Drainage Area	Elevation Above Mean Sea Level: Norm. Max. Headwater Level	Elevation Above Mean Sea Level: Normal Tailwater Level	Gross Head	Net Head	Height of Dam	Live Storage Volume: Volume	Live Storage Volume: % of Annual Flow	Average Flow	Index Capacity at Plant	Minimum Capacity Delivered	Primary Energy Delivered	Secondary* Energy Delivered	Additional Comb. Turbine Capacity	Total Investment Cost (Excl. IDC)	Net Annual Cost (Incl. IDC)	Index Cost (Incl. IDC)	Incremental Capacity Index (Incl. Tran.)	Transmission Index Cost (Excl. IDC)	
								Km	Km2	m	m	m	m	m	Km3		m3/s	MW	MW	GWh/A	GWh/A	-	106 US $	106 US $	US $/KWh	US $/KW	US $/KW	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)
								FIRST - ADDED SCHEME AFTER BASHA AND KALABAGH																				
1	YUGO	SHYOK	YG 31	0 0	S	B - 5	B 402	22	33700	2590	2440	_	_	165	5.9	55.4	338	_	_	_	_	_	1943	_	_	_	_	FOR STORAGE
2	SKARDU	INDUS	SK 31	0 2	S	B - 6	B 403	2550	112700	2316	2134	_	_	230	19	63.3	951	_	_	_	_	_	3829	_	_	_	_	SCHEME ONLY:
3	TUNGAS	INDUS	TG 112	0 4	P	B - 7	B 404	2339	113000	2134	1920	214	187	127	_	_	962	625	588	2809	1147	_	3472	568	0.202	2069	595	STORAGI
4	YULBO	INDUS	YB 122	0 4	P	B - 8	B 405	2289	114200	1920	1682	238	211	140	_	_	990	710	667	3190	1342	_	2852	432	0.135	1740	509	INDEX $(10^{6}\ \text{US}\$$
5	BUNJI	INDUS	JG 212	0 4	P	B - 9	B 406	2249	115600	1682	1280	402	379	210	_	_	1025	1290	1213	5793	2492	_	2689	335	0.058	964	291	$\text{KM}^{3})$
6	KANCH	GILGIT	KA 11	0 3	P	B - 10	B 407	102	9740	2013	1823	190	186	200	_	_	207	122	115	549	283	_	2759	478	0.871	3610	2814	329 202
7	SHER QILA	GILGIT	SQ 11	0 2	P	_	B 408	83	11000	1823	1702	121	119	130	_	_	234	88	83	395	203	_	3112	599	1.517	4620	3120	
8	RAKHIOT	INDUS	RK112	0 4	P	B - 11	B 409	2188	147600	1280	1160	120	118	140	_	_	1858	670	630	3010	1347	_	2216	291	0.097	952	450	
9	DASU	INDUS	DS 113 K	0 4	P	B - 12	B 410	2020	158700	975	760	215	211	235	_	_	2099	2712	2549	12181	4600	_	3107	332	0.027	391	132	
10	PATAN	INDUS	PT 112 S	0 8	P	B - 13	B 411	1990	160700	760	610	150	128	104	_	_	2254	1172	1102	7577	1119	590	2968	501	0.071	1647	135	
11	THAKOT	INDUS	BQ 132 S	0 4	P	B - 15	B 412	1952	162400	610	472	138	114	60	_	_	2337	1043	980	6897	923	565	2566	443	0.069	1879	114	
12	THAKOT	INDUS	BQ 232 S	0 1	P	B - 14	B 412	1952	162400	760	472	288	264	205	_	_	2337	2415	2270	15972	2137	1308	5200	947	0.064	921	92	
								FIRST - ADDED SCHEME AFTER BASHA WITHOUT KALABAGH																				
13	DASU	INDUS	DS 113	0 4	P	B - 12	B 410	2020	158700	975	760	215	211	235	_	_	2099	2398	2254	10767	4807	_	3044	312	0.029	416	143	
14	PATAN	INDUS	PT 111 S	0 2	P	B - 13	B 411	1990	160700	760	610	150	128	104	_	_	2254	1172	1102	7027	1496	449	2968	484	0.073	1647	135	
15	THAKOT	INDUS	BQ 131 S	0 6	P	B - 15	B 412	1952	162400	610	472	138	114	60	_	_	2337	1043	980	6619	1192	494	2566	431	0.07	1879	114	
16	THAKOT	INDUS	BQ 231 S	0 1	P	B - 14	B 412	1952	162400	760	472	288	264	205	_	_	2337	2415	2270	15328	2760	1144	5200	918	0.065	921	92	



D-3
D-4
P-4
6.0 km
6.7 km
7.5 km
5 Km
WATER AND POWER DEVELOPMENT AUTHORITY
GENERAL LOCATION
ALTERNATIVE PROJECT LAYOUT

COST EFFECTIVE ROADS FOR DEVELOPING COUNTRIES

By

Engr. Shaukat Ali

Necessity

Cost-effectiveness is a compulsory requirement of all developing countries because of invariable shortage of funds for more and more development works required each year. Because of limited resources developing countries usually do not have enough resources to meet the ever-increasing demands of emergent developments.

Necessity for cost-effectiveness, particularly in case of roads, has arisen because of irresistible tendency of softening of bituminous concrete supposed to be the strongest of all highway construction materials. What to speak of Saudi Arabia, Middle East, Israel, Pakistan and India, rutting in bituminous concrete has been observed even in U.S.A. not in hot regions of Arizona but even in New Jersey and New York.

Asphalt Concrete, supposed to be a material of every high modulus of resilience requiring sophisticated manufacturing, laying and testing costs more than 5 times the cost of granular base and almost 6 to 7 times the cost of sub-base. Now-a-days, it dominates the construction scenario in spite of its high cost and short-lived life. It starts rutting hardly within three years of opening the road to traffic. This period gets further reduced if climate is torrid and there is preponderance of heavier axle loads. Softening of bitumen is its inherent natural phenomenon. It gets further impetus because of its blackness and its avidity for rampant absorption of heat during summers of Saudi Arabia, Israel, Pakistan and other hot developing countries. It is not the mean annual average temperature or MAAT, which is being fallaciously and incorrectly presumed to be the culprit by proponents of pavement designers, it is the highest asphalt pavement temperature and its duration, which produces softening and consequently rutting. Moreover, it is the timely strike of the heavier axles, which aggravates the matter and initiates the rutting. This is such an irreversible process that rutting cannot but increase with the further passage of time and traffic. This is so because bitumen gets concentrated in the valleys and aggregates get shifted to the ridges of the ruts. With each passages of heavy vehicle over the valley containing concentrated softened bitumen rutting cannot but further accentuate and aggravate. Control on axle load will only help to the extent that the bitumen would not soften enough earlier to yield under the lighter wheel. Only the exact time for occurrence of rutting would get delayed because of the relatively lighter standard axle. Rutting on bituminous roads can only be arrested if the axle load is reduced to the level of cars and buses or if such a bitumen is used which does not soften upto 80°C. As per Pakistan experience, our road pavements reach as high a temperature as 80°C, for sufficiently longer part of the day.

Not only asphalt concrete is the costliest of all highway construction materials, it is also very expensive to rectify the rutting through the milling machines which them-selves are very expensive to buy. So long as we continue to use bituminous concrete as the primary road structural component, we shall continue to spend more money on milling and subsequent overlays. As per figures collected by NTRC Pakistan is spending as much as Rupees Two Billion each year on bituminous concrete.

In the above scenario there is immediate need to minimize or eliminate bituminous concrete by using alternative methods of design and construction which should be cost-effective to construct and to maintain.

We, in the developing countries, should be quite wary and cagey in adopting high technological techniques of the developed West in the name of transfer of technology ; because what suits their traffic pattern, driving habits, weather conditions and environments may not suit us unless intelligently applied or suitably modified.

Cost-effectiveness in developing countries even otherwise is vitally necessary because of the perpetual paucity of sufficient funds required to construct enough roads to meet the ever increasing demands of communication sector and public demand of more roads as a result of the process of development. More roads can only be built if each rupee is spent economically and cost effectively. If cost-effectiveness is not given due importance more foreign aid shall be needed or other vital development activities shall need to be curtailed.

Cost-effectiveness is therefore a sine qua non for sustainable development. It is an unavoidable must in highway construction especially in view of the utter failure of the asphalt concrete in the last two decades in Pakistan.

Cost-effectiveness is something, which is desirable not only for developing countries but also for the developed ones. We in the developing countries should effect cost-effectiveness not only by eliminating such white elephants as the bituminous concrete but also by maximizing the use of indigenous materials, indigenous machinery and indigenous resources through exhaustive indigenousization.

How cost-effectiveness can be effected in road construction in Pakistan and *mutatis mutandis* in other developing countries calls for deeper analysis.

Cost-Effectiveness

The main culprit in road construction, which considerably enhances its cost of construction as well as cost of maintenance stands identified as the bituminous concrete in wearing course and base course. As much as 25 to 40 percent saving in cost of construction can be effected if bituminous concrete is either minimized or totally eliminated and other cost-effective materials are used on the basis of a new design not banking on its pseudo-strength. Recent analytical designs assume highest modulus of resilience value of bituminous concrete and take it as the strongest of all the road construction materials assuning its value to be constant at all pavement temperatures. All the developed countries are adopting the value of modulus of resilience of bituminous concrete at average annual mean temperature of 20 to 23°C. This temperature is quite relevant for moderate to cold countries but cannot be applied to predominantly hot developing countries like Pakistan. In Pakistan road pavement temperature goes as high as 80°C because of persistent absorption of heat for major part of the day for months together. As a matter of fact, at such high temperatures, bituminous concrete does not remain elastic and its modulus of resilience drops from 500,000 psi at 20°C to less than that of even sub-base at above 60°C.

Adoption of 20°C by the developed countries in cold environs could not be as wrong as it is in a hot country like Pakistan. Moreover, at temperature higher than about 40°C, asphalt concrete does not remain elastic and as such, at high temperatures it can not be assumed to be an elastic material nor its elastic modulus can be used as the basis for any sustainable analytical design.

The traffic load on the road is to be ultimately borne by the soil over which it rests. Traffic load gets transferred to the native soil through the road structure of sub-base, base and surfacing generally known as the road crust.

The road crust is the total pavement structure resting over the native soil which takes all the stresses and strains of traffic. It comprises of the sub-grade, the sub-base and the base in addition to the wearing course. Normally the native soil and the sub-grade do not differ in structural composition except in degree of compaction. If the native soil is too weak or is likely to become too weak to take traffic load sub-grade would need stabilization. Since the primordial idea of provision of road crust is to spread load over greater area of the native soil, each material forming part of the crust must be stronger than the one below. Thus wearing course must be stronger than the base while the base must be stronger than the sub-base and similarly the sub-base stronger than the sub-grade. The native soil can be in cutting or in filling depending upon the road profile and topography of the terrain.

Functions of Road Crust

The rudimentary function of the road crust is to spread the traffic load over greater area of the native soil. Spread of load over the greater area is directly related to the thickness of the crust. As we move from the native soil upward crust thickness gradually decreases and conversely traffic pressure increases. Thus traffic pressure at the top of base shall be more than pressure at the top of sub-base and similarly traffic pressure at top of sub-base shall be more than the pressure at the top of sub-grade and so on. Boussinesq Pressure Bulb Theory and time old Rankine theory also support this premise. By provision of adequate thickness of road crust the pressure on the native soil can be reduced to the extent to enable it to take the traffic load without sinking of heaving and without producing any adverse or mal-effect on the performance of the road.

Apart from exerting pressure, traffic wheel also tends to produce tension in the bottom fiber and compression at the top fiber with a tendency to produce deflection in the road momentarily for a minuscule fraction of a second. With adequately thick crust not only the pressure on the native soil becomes incredibly low the deflection resulting from low pressure also becomes practically too immaterial to have any adverse effect on the road crust and its long-term performance. We can effect cost-effectiveness if we can prolong the performance of the road at minimum maintenance cost. This is only possible with thicker road crust.

If the road crust is adequately thick there shall be no tension in the bottom fiber for all intents and purposes and the native soil shall be in compression only. It is for this reason very essential to have thicker road crust in all eventualities. We can have long-lasting road only with thicker road crust. Hence the necessity and importance of provision of adequately thick road crust.

FUNCTIONS OF ROAD CRUST COMPONENTS

The Sub-grade

Top one foot thick portion of native soil is especially stabilized / compacted to make it fit for being structural part of the crust both for spreading the traffic load over greater area of native soil as well as having more structural strength than the native soil itself.

Strength of the native soil and stone aggregate layers acting as sub-base or base is measured by observing resistance to penetration of a standard plunger having a specified area. This resistance to penetration is called California Bearing Ratio. Sub-grade becomes structural part of the road crust only if its CBR as well as compaction is more than the natural soil. Provision of sub-grade becomes vitally important if the CBR of the native soil is too poor to guarantee its proper behaviour. Hence the function of the sub-grade is to provide adequately strong foundation for laying the sub-base.

The Sub-Base

The primary function of sub-base, apart from distribution of load over greater area of sub-grade, is to provide a stronger foundation for the base. It should also act as a moisture-rise barrier against capillary rise and salt-rise barrier against salts present in the sub-grade and the native soil. In case the sub-grade becomes over-moisturized due to capillary rise from below or ingress of precipitation from above, it should suck up the moisture as a blotting paper or should drain it off towards the sides because of the presence of the in-built side slopes of normal crown or camber provided in the sub-grade during construction. As a corollary, it should also become stronger in the presence of moisture when normal A-4 soil becomes weaker in the presence of moisture. It is, therefore, necessary that the sub-base material should be sandy and drain-able. It is only the sand, which because of the pore pressure becomes stronger in the presence of moisture and yet remains drain-able. As such sub-base must have adequately high CBR and must be highly sandy or drain-able. Drain-ability can be dispensed with only in an area having no possibility of rise of water from below or ingress of moisture from above because of every little precipitation.

The Base

The base, being nearer to the traffic load, is subjected to greater stress and strain and as such it should have greater structural strength, greater CBR and greater stability. Repeated movement of traffic produces inter-granular movement from native soil up to the top of the crust. Depending upon thickness this movement is the feeblest in the native soil and severest in the base. For this reason, a very strong base is required which may absorb the repeated and reversible inter-granular movements in all eventualities and in all vagaries of weather. Inter-granular movement in base and to some extent in sub-base can only be resisted by a structurally strong stone so completely interlocked that it may become impossible for the traffic load to break its bond, but permitting innocuous movement, and allowing it to be still flexible. Developed countries having moderate to cold climate have found bituminous concrete as the strongest of all materials so far as flexible pavements are concerned. Bituminous concrete stymies the inter-granular movement but softens in very hot environments and succumbs under the heavy axle wheel and loses structural strength. In torrid areas of Pakistan bituminous concrete as base has miserably failed under heavy axled traffic except for city roads where heavy axled traffic is not allowed to ply.

So far as the aspect of cost-effectiveness is concerned, bituminous concrete, for hot developing countries having preponderance of heavy axled traffic in their highway plexus is least suitable and helpful as it softens at high pavement temperatures.

High structural strength, high California Bearing Ratio and long term performance in base can be achieved by maximizing the use of crushed stone with optimal stone to stone interlocking. Sufficiently thick well-locked stone aggregate can impart high structural strength to base. Because of inter-locking, it will become semi-rigid and strong enough to spread traffic load over much greater area of the sub-base. It will, thus, become so strong as to take the brunt of heavy axled traffic year after year in all vagaries of weather without any fear of drop of structural strength.

Wearing Surface

The function of wearing surface is to provide an impermeable smooth and jump-free surface, which could take the brunt of traffic without yielding and could give a jolt-free ride year after year without bleeding, rutting or corrugating. Bituminous concrete when used as wearing course softens and yields during sultry summers under heavy axle loads and consequently ruts. This phenomenon can only be made tolerable if its thickness is kept least possible or instead of asphalt concrete surface treatment is adopted. For developing countries, as shall be explained later, surface treatment is highly cost-effective as compared to the bituminous concrete. Surface treated road topping can be as satisfying as the asphalt concrete if proper care is exercised in maintaining and achieving excellent riding quality in reaching the top of the base surface and if a sand seal smoothening coat is additionally provided on top of the surface treatment. Like asphalt concrete surface treatment has all the potentialities of sealing the top of the road and making it impermeable to precipitation besides making it jolt and jump-free to road users. Moreover, it neither requires a large fleet of machinery to manufacture and lay nor foreign expertise. In surface treatment we are more expert than the developed countries.

COST-EFFECTIVENESS

Once we know the function of road crust and its structural components we can think of devising ways and means of economizing keeping in view our environs, the materials and resources available with us. While elaborating my point of view, I shall keep Pakistan in view in particular and developing countries in general. The experience gained in Pakistan can be applied *mutatis mutandis* to other developing countries.

General recommendation and advice of the developed countries usually is to provide bituminous wearing course as well as base course since according to them it is the strongest of all the road construction materials and has the highest modulus of resilience value as per latest state of art of design. Moreover, it can easily be worked out with the assistance of now-a-days available computers. As per research carried out by the developed countries when most of the developed countries are of cold and moderate climate, bituminous concrete has the highest layer coefficient value. Ipso facto they advise us to maximize the provision of bituminous concrete both for base as well as wearing course and use full depth asphalt concrete. This is what we did in Pakistan on majority of our roads and we went so far as to provided almost one foot thick bituminous concrete as per requirements of the mechanistic design. Thicker the asphalt concrete, more likely it is to soften and to rut.

Bitumen is very expensive and so is the bituminous concrete which becomes almost as expensive as good quality cement concrete because of inherent high cost of bitumen and exorbitantly costly machinery required for its manufacture and laying under highly specialized technical staff. Most of the developing countries are not manufacturing such sophisticated machinery as Asphalt Plants, Paver-Finishers, Tandem Rollers, Pneumatic Tyred Rollers and Dump Trucks. It therefore, becomes necessary for them to beg aid from the developed countries to import machinery and expatriate staff for laying bituminous concrete, base course and wearing course. This immensely increases the cost of construction since some developing countries have not only to get machinery and technical staff imported but also to import bitumen. Tremendous increase in cost is one aspect of bituminous concrete base and wearing courses, while the other aspect is that notwithstanding the applications of latest state of art of design and construction, it has miserably failed even in moderately hot countries like Pakistan. It has failed in spite of most rigid and literal application of specifications, site supervision and strictest control in manufacturing and paving. In spite of the fact that the expatriate asphalt specialists fully knew the extent of preponderance of high-axled traffic on our roads, rutting could not be stopped.

Present method of construction of roads as per advice of the developed countries is not only expensive and least cost-effective, it is also not sustainable. Roads built presently either need to be milled or reconstructed or overlaid to conceal the defects, which develop within hardly a period of three to five years. This is too short a period for a developing country to afford because of the ever-increasing pressure of construction of still more roads.

NEED FOR NEW STRATEGY OF DESIGN AND CONSTRUCTION

The sum total of what I have said so far is that if we have to construct long lasting roads and if we have to effect cost-effectiveness, we must change our strategy of design and construction. The present strategy is not only machinery-oriented and foreign-exchange-demanding but also least pro-indigenous. Another vitally significant aspect of present design being followed is that it does not suit the developing countries. Especially those whose summer temperature far exceeds 45°C and road pavement temperature exceeds 65°C. Roads built in such hot countries with substantial asphalt-concrete thicknesses succumb and yield permanently in the form of irretrievable ruts within hardly 3 to 5 years. Rutting, developed in this way, gets accentuated with the passage of time and can only be partially corrected through a highly costly milling machine. Milling minimize the ruts but makes the road surface highly abrasive to tyres whose life is halved unless the milled surface is retreated with overlay of asphalt concrete or surface treatment. The present system of road construction is therefore, too expensive to be afforded by developing countries and too short-lived to be continued.

Discarding mechanistic design and bituminous concrete especially for flexible pavements becomes vitally important because of exorbitant cost of construction, sophisticated supervision and still more importantly because of its short-life, high cost of its milling and overlaying after rutting. It has been observed that milled surface further easily ruts with each overlay. Still more reason for its rejection is its lack of cost-effectiveness which developing countries can hardly afford.

Presently because of excessive thickness of asphalt concrete supposed to be acting both as base and wearing course, the overall thickness of the road crust is generally too low to substantially reduce pressure on the native soil. The result is that the remaining crust is subjected to greater stresses and strains and cannot act as a permanent foundation for a lasting road. Adoption of new cost-effective strategy seems to be a *sine qua non* if we want to build sustainable road plexus in developing countries. Strategic Highway Research Program of highly developed countries is also bitumen-oriented and bitumen-intensive and as such shall not help us nor would suit us because of its complex testing and design techniques which have yet to prove their sustainability in torrid environs.

It is possible to avoid preponderance of asphalt concrete in the road crust and yet be cost-effective ? Yes, it is possible for all developing countries to save cost in construction, minimize dependence of foreign exchange and have far durable roads with the least maintenance cost without bituminous concrete as the primary road crust component.

Let us probe this premise further. Both the specifications and the method of construction as recommended and advised by the developed countries are as a matter of fact the ones as suit them as per their resources and their climatic conditions. Both are machinery-intensive and machinery-oriented. According to these specifications and method of construction roads cannot be built without extensive use of imported machinery and involvement of sophisticated technology regardless of cost involved. In these specifications there is more emphasis and stress on gradation for sub-base and base for ease in grading and to some extent compaction than on the long term performance of the road thus built. Moreover, the mechanistic design as recently adopted in preference to time-tested empirical designs also lays emphasis on extensive use of bituminous concrete. In other words neither the mechanistic design nor the method of construction, nor the specifications of developed countries suit the developing countries. Moreover, these are also not cost-effective because of intensive demand of imported machinery and sophisticated technologies as well as the intensive and extensive use of costliest of all highway construction materials i.e. bitumen.

There is, therefore, immediate need for adoption of alternative methods of performance oriented design and construction, which should not only be cost-effective but also longer lasting than the one advised by the developed countries. Developed countries have in a way compelled us to follow their method of construction and their specifications almost literally in name of transfer of technology.

Design Strategy

Performance-oriented design shall be primarily empirical design based on experience gained in developing countries like Pakistan and shall be applied mutandis to other developing countries keeping in view the climatic as well as traffic and loading variations of the developing countries.

The design strategy would be that a structural number shall be arrived at keeping in view the traffic, its growth rate as well as the design period preferably 20 years as per AASHTO Design. From the design structural number thus arrived specific thickness shall be assigned to sub-base, base and wearing course keeping wearing course at the pessimum and aggregate sub-base and base at such an optimum that overall cost of the crust is minimum. By adopting surface treatment, eliminating bituminous base and wearing course and preferring stone aggregate sub-base and base substantial saving can be effected.

PERFORMANCE ORIENTED CONSTRUCTION

Road construction can be performance oriented only if the traffic pressure on the native soil always remains within its safe limits by adopting suitably thicker road crust. It is the native soil that has ultimately to take all the brunt of the traffic load. No mechanistic design or any magic wand would help unless the pressure on the soil gets reduced to the extent that the soil can bear traffic load in whatever worst state it is. Traffic load applied over thin rigid single or multiple layers resting over infinite elastic earth mass tends to produce deflection and consequently tension in the bottom fibers and compression in the top fibers. When the rigidity diminishes and thickness increases tension in bottom fibers becomes too insignificant to affect the structural behaviour of the granular road crust and the entire traffic load gets transmitted as compression in a flexible pavement. It is the compressive stress which ultimately reaches the native soil and this stress in all eventualities should be such a stress as can easily be taken by the soil.

Stress over the native soil can be further reduced by creating semi-rigidity in the stone aggregate sub-base and base through stone to stone and inter-granular friction. This can be done by managing sharp edges in the stone aggregate by hand breaking and filling the intra-grain space with crushed stone slurry or sand as per requirement of base or sub-base. Interlocking coupled with adequate thickness of the crust reduces the pressure on the native soil so considerably that all possibilities of its future settlement get minimized. Sub-base and base in such a milieu are most likely to act as almost permanent road foundation because of least inter-granular movement of stone as a result of interlocking and choking of the interstices with slurry in case of base and sand in case of sub-base.

RUTTING FREE WEARING COURSE

There is no guarantee to the softening of the asphalt concrete during hot summer days under heavy axles if the thickness of the bituminous concrete is as low as 50 mm. For ensuring rutting free wearing course we have no other alternative except to resort to surface treatment with a sealing or smoothening coat to have the same type of wearing surface as the asphalt concrete.

Surface treatment because of stone to stone contact and minimum quantity of bitumen is least rutting-prone and will not rut unless the base over which it rests sinks down because of lack of compaction. If by mistake excessive bitumen is used and bleeding takes place, it can easily be rectified by repeat spreading of sand or stone dust over the bleeded area. The surface treatment, being presently carried out on roads of lesser importance is not the one, which is being championed here. If it is to replace bituminous concrete it must be quality surface treatment. For quality surface treatment broad specifications are elaborated in what follows.

Surface Treatment

Surface treatment especially multiple surface treatment has great potential to completely replace asphalt concrete at less than half the cost of the asphalt concrete. Moreover, surface treatment has the in-built and inherent economic benefits of providing employment to thousand of workers besides reducing electric consumption and import of construction machinery as well as spare parts. In addition, it has the potential of giving boost and incentive to local manufactures of indigenous machinery and of effecting substantial saving in foreign exchange to the great chagrin of the loan-givers who do not want the developing countries to escape from their ever-tightening tentacles.

River-run round gravel should always be preferred over crushed aggregate because of its superiority in offering resistance to wear, impact and weathering as well as its ability to offer least resistance to movement of wheel.

Surface treatment should not be carried out when the ambient temperature is less than 30 C, it should be carried out when it is preferably more. When the aggregate is highly dusty or when there is excessive humidity or during and immediately after rains, surface treatment should be avoided. This will be so because excessive dust will act as barrier between the bitumen and the aggregate. In such a situation, the aggregates are likely to strip, revel or shove under the traffic. When the aggregate is wet or humid, water should play the similar role of a barrier between the bitumen and the stone and this would ultimately tell upon the performance of surface treatment.

In cold countries there is very little possibility of the success of the type and quality of surface treatment I am talking about The surface treatment which can match in performance to asphalt concrete cannot be carried out in cold countries because it is only rare when ambient temperature in such countries is above 30 C. IN cold climates surface treatment is carried out with cold emulsion. This is too weak to bear the brunt of heavy traffic and is no match to hot weather surface treatment.

Surface treatment has not only large potential but also a wide spectrum of applications. Surface treatment could be single coat, double coat or triple coat or as many coats excluding the smoothening coat as necessary to meet the specific traffic and loading requirements. A large variety of surface treatment application paradigms are given below as a guide-line. This is in accordance with the basic principles of surface treatment and empiricism of 10 decades.

SURFACE TREATMENT APPLICATION PARADIGMS

The following are the various application paradigms of surface treatment, which can be made use of for a host of construction variations and situations as per the exigencies of execution. I shall start from typical single coat to double coat and then from application on tertiary roads to primary roads including national highways and those roads where extra heavy treatments are called for. The quantity of bitumen and the rate of spread of bajri or crushed aggregate, specifically pertains to the exact size of the aggregate mentioned here below. In case the size is even slightly reduced the quantity of bitumen and aggregate will have to be reduced accordingly otherwise the surface treatment may bleed.

In the following tables SCA-8 means Single Coat Application No. 8, DCA-5 means Double Coat Application No. 5, TCA-3 means Three Coat Application No. 3 and MCA-7 means Multiple Coat Application No. 7 etc.

Single Coat Applications

The various applications of surface treatment are as under :

Table No.	Aggregate Per Hundred Square Feet		Bitumen Per Hundred Square Feet
	Size	Qty.	
SCA-1	Coarse Sand	½ Cft.	5 Lbs.
SCA-2	1/8"	¾ Cft.	8 Lbs.
SCA-3	¼"	1 ½ Cft.	14 Lbs.
SCA-4	3/8"	2 Cft.	18 Lbs.
SCA-5	½"	2 ½ Cft.	22 Lbs.
SCA-6	¾"	4 Cft.	35 Lbs.
SCA-7	1"	5 ½ Cft.	45 Lbs.
SCA-8	1 ½"	8 Cft.	60 Lbs.
SCA-9	2"	11 Cft.	75 Lbs.

Double Coat Applications

Table No.	Aggregate Per Hundred Square Feet		Bitumen Per Hundred Square Feet
DCA-1	Size	Qty.	
	¼"	1 ½ Cft.	14 Lbs.
	1/8"	¾ Cft.	8 Lbs.
		2 ¼ Cft.	22 Lbs.

Table No.	Aggregate Per Hundred Square Feet		Bitumen Per Hundred Square Feet
DCA-2	Size	Qty.	
	3/8"	2 Cft.	18 Lbs.
	¼"	1 ½ Cft.	14 Lbs.
		3 ½ Cft.	32 Lbs.

Table No.	Aggregate Per Hundred Square Feet		Bitumen Per Hundred Square Feet
DCA-3	Size	Qty.	
	3/8"	2 Cft.	18 Lbs.
	1/8"	¾ Cft.	8 Lbs.
		2 ¾ Cft.	26 Lbs.

Table No.	Aggregate Per Hundred Square Feet		Bitumen Per Hundred Square Feet
DCA-4	Size	Qty.	
	½"	2 ½ Cft.	22 Lbs.
	¼"	1 ½ Cft.	14 Lbs.
		4 Cft.	36 Lbs.

Table No.	Aggregate Per Hundred Square Feet		Bitumen Per Hundred Square Feet
DCA-5	Size	Qty.	
	½"	2 ½ Cft.	22 Lbs.
	1/8"	¾ Cft.	8 Lbs.
		3 ¼ Cft.	30 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
DCA-6	Size	Qty.	
	½"	2 ½ Cft.	22 Lbs.
	3/8"	2 Cft.	18 Lbs.
		4 ½ Cft.	40 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
DCA-7	Size	Qty.	
	¾"	4 Cft.	35 Lbs.
	3/8"	2 Cft.	18 Lbs.
		6 Cft.	53 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
DCA-8	Size	Qty.	
	¾"	4 Cft.	35 Lbs.
	½"	2 ½ Cft.	22 Lbs.
		6 ½ Cft.	57 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
DCA-9	Size	Qty.	
	1"	5 ½ Cft.	43 Lbs.
	½"	2 ½ Cft.	22 Lbs.
		8 Cft.	65 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
DCA-10	Size	Qty.	
	1"	5 ½ Cft.	43 Lbs.
	3/8"	2 Cft.	18 Lbs.
		7 ½ Cft.	61 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
DCA-11	Size	Qty.	
	1 ½"	8 Cft.	56 Lbs.
	¾"	4 Cft.	28 Lbs.
		12 Cft.	84 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
DCA-12	Size	Qty.	
	1 ½"	8 Cft.	56 Lbs.
	½"	2 ½ Cft.	22 Lbs.
		10 ½ Cft.	78 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
DCA-13	Size	Qty.	
	2"	11 Cft.	77 Lbs.
	1"	5 ½ Cft.	38 Lbs.
		16 ½ Cft.	115 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
DCA-14	Size	Qty.	
	2"	11 Cft.	77 Lbs.
	¾"	4 Cft.	28 Lbs.
		15 Cft.	105 Lbs.

The riding quality of double surface treatment of two coat work will be highly non-skid and rough to drive at with micro-hogs and micro-sags which shall need to be smoothened with fine coats of 1/8" and sand seal. The quantity in two coat work stands strategically reduced in certain applications to avoid contractors playing with the bitumen.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
TCA-1	**Size**	**Qty.**	
	½"	2 ½ Cft.	22 Lbs.
	¼"	1 ½ Cft.	14 Lbs.
	1/8"	¾ Cft.	8 Lbs.
		4 ¾ Cft.	44 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
TCA-2	**Size**	**Qty.**	
	¾"	4 Cft.	35 Lbs.
	3/8"	2 Cft.	18 Lbs.
	¼"	1 ½ Cft.	14 Lbs.
		7 ½ Cft.	67 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
TCA-3	**Size**	**Qty.**	
	¾"	4 Cft.	35 Lbs.
	3/8"	2 Cft.	18 Lbs.
	1/8"	¾ Cft.	8 Lbs.
		6 ¾ Cft.	61 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
TCA-4	Size	Qty.	
	1"	5 ½ Cft.	38 Lbs.
	½"	2 ½ Cft.	20 Lbs.
	¼"	1 ½ Cft.	14 Lbs.
		9 ½ Cft.	72 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
TCA-5	**Size**	**Qty.**	
	1"	5 ½ Cft.	38 Lbs.
	3/8"	2 Cft.	18 Lbs.
	1/8"	¾ Cft.	8 Lbs.
		8 ½ Cft.	64 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
TCA-6	**Size**	**Qty.**	
	1 ½"	8 Cft.	64 Lbs.
	¾"	4 Cft.	30 Lbs.
	3/8"	2 Cft.	18 Lbs.
		14 Cft.	112 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
TCA-7	**Size**	**Qty.**	
	1 ½"	8 Cft.	64 Lbs.
	½"	2 ½ Cft.	23 Lbs.
	¼"	1 ½ Cft.	14 Lbs.
		12 Cft.	101 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
TCA-8	Size	Qty.	
	2"	11 Cft.	77 Lbs.
	1"	5 ½ Cft.	38 Lbs.
	½"	2 ½ Cft.	20 Lbs.
		4 Cft.	135 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
TCA-9	Size	Qty.	
	2"	11 Cft.	77 Lbs.
	¾"	4 Cft.	28 Lbs.
	3/8"	2 Cft.	18 Lbs.
		17 Cft.	123 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
TCA-10	Size	Qty.	
	2"	11 Cft.	77 Lbs.
	¾"	4 Cft.	28 Lbs.
	¼"	1 ½ Cft.	14 Lbs.
		16 ½ Cft.	119 Lbs.

Mini-hogs and mini-sags will be more predominant in coarser three coat applications and there shall be all the more necessity to smoothen them and make them acceptable to road users by applying two additional coats. One coat of 1/8 " thick fine aggregate and another coat of coarse sand seal.

Multiple Coat Applications

With multiple applications not only the thickness of surface treatment can be increased, its structural contribution can also be enhanced substantially. It would thus become indigenous asphalt concrete without any asphalt plant, without deployment of large fleet of asphalt machinery, without going into the intricacies of job mix formula and its approval and without any engagement of asphalt experts.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
MCA-1	Size	Qty.	
	2"	11 Cft.	77 Lbs.
	1"	5 ½ Cft.	38 Lbs.
	½"	2 ½ Cft.	22 Lbs.
	¼"	1 ½ Cft.	14 Lbs.
	1/8"	¾ Cft.	8 Lbs.
	Coarse Sand	½ Cft.	5 Lbs.
		21 ¾ Cft.	164 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
MCA-2	Size	Qty.	
	1 ½"	8 Cft.	64 Lbs.
	¾"	4 Cft.	32 Lbs.
	3/8"	2 Cft.	18 Lbs.
	3/16"	1 Cft.	10 Lbs.
	Coarse Sand	½ Cft.	5 Lbs.
		15 ½ Cft.	129 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
MCA-3	Size	Qty.	
	1"	5 ½ Cft.	44 Lbs.
	½"	2 ½ Cft.	22 Lbs.
	¼"	1 ½ Cft.	14 Lbs.
	1/8"	¾ Cft.	8 Lbs.
	Coarse Sand	½ Cft.	5 Lbs.
		10 ¾ Cft.	93 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
MCA-4	Size	Qty.	
	¾"	4 Cft.	35 Lbs.
	3/8"	2 Cft.	18 Lbs.
	3/16"	1 Cft.	10 Lbs.
	Coarse Sand	½ Cft.	5 Lbs.
		7 ½ Cft.	68 Lbs.

Table No.		Aggregate Per Hundred Square Feet	Bitumen Per Hundred Square Feet
MCA-5	Size	Qty.	
	½"	2 ½ Cft.	22 Lbs.
	¼"	1 ½ Cft.	14 Lbs.
	1/8"	¾ Cft.	8 Lbs.
	Sand	½ Cft.	5 Lbs.
		5 ¼ Cft.	49 Lbs.

In the presence of the above plethora of surface treatment paradigms we have large choice of application which completely renders asphalt concrete unnecessary.

SAVING IN COST BY MINIMIZING ASPHALT CONCRETE

ISLAMABAD HIGHWAY

ROAD PAVEMENT WITH ASPHALT CONCRETE				EQUIVALENT STONE AGGREGATE PAVEMENT			
Road Component	Thick-ness	Structural Contribution	Cost Per ft.^{2} (Rs)	Road Component	Thick-ness	Structural Contribution	Cost Per ft.^{2} (Rs)
Sub-Base	150 mm	0.66	5.63	Sub-Base	375 mm	1.65	14.10
Aggregate Base	225 mm	1.26	8.83	Aggregate Base	375 mm	2.10	14.71
Asphaltic Base	100 mm	1.76	47.83	Asphaltic Base	0 mm	0.00	0.00
Wearing Course	50 mm	0.88	23.69	Wearing Course	50 mm	0.88	23.69
		4.56	85.98			4.63	52.50

Saving 33.48

Saving % 38.94 % Say 39 %

LAHORE ISLAMABAD MOTOWAY M-2

ROAD PAVEMENT WITH ASPHALT CONCRETE				EQUIVALENT STONE AGGREGATE PAVEMENT			
Road Component	Thick-Ness	Structural Contribution	Cost Per ft.^{2} (Rs)	Road Component	Thick-ness	Structural Contribution	Cost Per ft.^{2} (Rs)
Sub-Base	150 mm	0.66	8.00	Sub-Base	400 mm	1.76	21.33
Aggregate Base	300 mm	1.68	20.00	Aggregate Base	350 mm	1.96	23.33
Asphaltic Base	80 mm	1.38	36.26	Asphaltic Base	0 mm	0	0.00
Wearing Course	50 mm	0.88	23.63	Wearing Course	50 mm	0.88	23.63
		4.60	87.98			4.60	68.29

Saving 19.60

Saving % 22.30 %

ISLAMABAD PESHAWAR MOTOWAY M-1 (Rashkai-Charsadda)

ROAD PAVEMENT WITH ASPHALT CONCRETE				EQUIVALENT STONE AGGREGATE PAVEMENT			
Road Component	**Thick-Ness**	**Structural Contribution**	**Cost Per ft.² (Rs)**	**Road Component**	**Thick-ness**	**Structural Contribution**	**Cost Per ft.² (Rs)**
Sub-Base	150 mm	0.66	7.00	Sub-Base	425 mm	1.87	19.83
Aggregate Base	250 mm	1.40	15.00	Aggregate Base	350 mm	1.96	21.00
Asphaltic Base	100 mm	1.76	44.88	Asphaltic Base	0.0 mm	0	0.00
Wearing Course	50 mm	0.88	23.63	Wearing Course	50 mm	0.88	23.63
		4.60	90.51			4.71	64.46

Saving 26.05

Saving % 28.78 %

ISLAMABAD PESHAWAR MOTOWAY M-1 (Islamabad-N5 Section)

ROAD PAVEMENT WITH ASPHALT CONCRETE				EQUIVALENT STONE AGGREGATE PAVEMENT			
Road Component	**Thick-Ness**	**Structural Contribution**	**Cost Per ft.² (Rs)**	**Road Component**	**Thick-ness**	**Structural Contribution**	**Cost Per ft.² (Rs)**
Sub-Base	150 mm	0.66	7.00	Sub-Base	500 mm	2.20	23.33
Aggregate Base	250 mm	1.40	15.00	Aggregate Base	475 mm	2.66	28.50
Asphaltic Base	160 mm	2.82	72.53	Asphaltic Base	0.0 mm	0.00	0.00
Wearing Course	50 mm	0.88	23.63	Wearing Course	50 mm	0.88	23.63
		5.76	118.16			5.74	75.46

Saving 42.70

Saving % 36.14 %

RAHIMYAR KHAN UBARO-N5

ROAD PAVEMENT WITH ASPHALT CONCRETE				EQUIVALENT STONE AGGREGATE PAVEMENT			
Road Component	**Thick-ness**	**Structural Contribution**	**Cost Per ft.² (Rs)**	**Road Component**	**Thick-ness**	**Structural Contribution**	**Cost Per ft.² (Rs)**
Sub-Base	150 mm	0.66	7.00	Sub-Base	700 mm	3.08	32.66
Aggregate Base	300 mm	1.68	16.00	Aggregate Base	625 mm	3.50	33.33
Asphaltic Base	240 mm	4.22	108.80	Asphaltic Base	0 mm	0.00	0.00
Wearing Course	50 mm	0.88	23.63	Wearing Course	50 mm	0.88	23.63
		7.44	155.43			7.46	89.62

Saving 65.81

Saving % 42.34 %

COST COMPARISON OF AGGREGATE BASE RATE WITH ASPHALT CONCRETE RATE

S. No.	Project		Rate of Aggregate Base/M^3	Rate of Asphalt Base/M^3	Asphalt Base Cost is .... Times the cost of aggregate base
1.	Chablat – Nowshehra N-5	(1994)	300.00	2,750.00	9.16
2.	Peshawar – Torkham N-5	(1996)	205.00	2,507.00	12.23
3.	Sakkar Bye Pass	(1995)	500.00	4,250.00	8.50
4.	Bridge over Indus River, Larkana	(1995)	650.00	4,250.00	6.54
5.	Islamabad Expressway	(1999)	415.00	5,068.00	12.19
6.	Chak Behni – Sahiwal N-5 (6-A)	(1990)	370.00	3,420.00	9.24
7.	Chak Behni – Chichawatni (6-B)	(1990)	350.00	3,480.00	9.94
8.	Ghazi Brotha Hydro Power Project	(1996)	308.49	3,484.30	11.29

The greatest saving would be the saving that would result from longer life of the road, Structural texture of the road, because of the well-interlocked sub-base and base, would be such that road shall continue to take the stress and strain of the traffic much more than two to three decades. Only the surface treatment would need renewal, the road infra-structure of sub-base and base would remain practically unover-stressed because of lesser stress and strain at the native soil level and correspondingly in the other layers.

For academic interests analytical design of flexible pavements may be further probed and perfected but so long it is not cost-effective and sustainable in all vagaries of weather and conditions of loading, it is no use applying it.

In the above examples of minimizing bituminous concrete with the same structural number, bituminous concrete of minimum 50 mm thickness gives cost-saving as high as 40%. This saving would increase beyond 50% if asphalt concrete is totally eliminated and replaced with quality surface treatment.

Engineers having vast experience of highway construction of Saudi Arabia and having little exposure of surface treatments feel that surface treatment cannot take the brunt of heavy-axle traffic. Their misgivings are natural because they do not have enough experience of surface treatment. In the Seminar of August 5, 2003, NHA has admitted that the actual performance in the field of water-bound macadam is far better than that of ordinary aggregate base. The representative of the Punjab Highway Department also confirmed this. I may point out that in all the length and bredth of Punjab, wherever it is water-bound macadam, it is invariably overlaid with surface treatment. Performance of water-bound macadam is as a matter of fact also the performance of surface treatment.

USE OF GEO-SYNTHETICS IN PAVEMENT CONSTRUCTION

By

Engr. Shahid Mahmood*

INTRODUCTION

Historically, major developments in Civil Engineering have only been possible because of parallel developments in the technology of construction materials. Larger and more elaborate structures became possible as we went from using wood to building stone to concrete to reinforced concrete and most recently to prestressed concrete.

The development of steel enabled the construction of longer span bridges and taller buildings which were not possible by using of traditional materials.

In the field of Highway Engineering, probably the best example of parallel development between material and construction application in invention of "GEO-SYNTHETIC" materials.

There are few developments that have a rapid growth and strong influence on so many aspects of Civil Engineering practice as geo-synthetics.

In 1970, there were only five or six geo-synthetics available, while today more than 600 different geo-synthetics are sold throughout the world.

Worldwide annual consumption of geo-synthetics is about 1000 million square meters and the value of these materials is ranging up to 1500 million US Dollars.

In many cases, the use of geo-synthetics can significantly increase the safety factor, improve performance and reduce the cost in comparison with traditional construction materials.

WHAT ARE "GEO-SYNTHETICS"

These are the products manufactured from polymeric materials like :

Polypropylene, Polyester, Polyethylene, Polyvinyl Chloride (PVC)

And many products are manufactured by natural materials like :

Cotton, Jute, Reeds, Grass, Bamboo, Palm wood etc.

PROPERTIES OF GEO-SYNTHETICS

(1) High tensile strength (2) High puncture resistance (3) Durable against chemical and biological effects (4) Permeability (Depending upon site conditions)

M.Sc. Structural Engg.

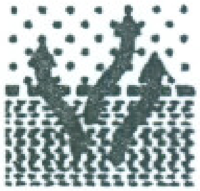
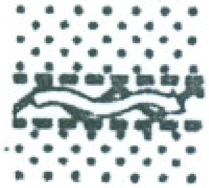
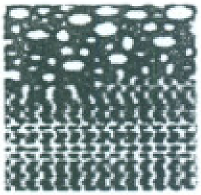
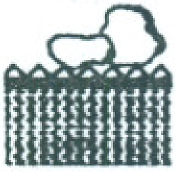
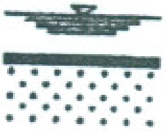
CLASSIFICATION OF GEO-SYNTHETICS

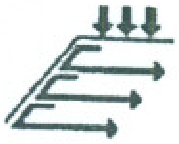
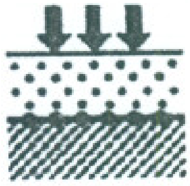
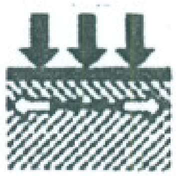
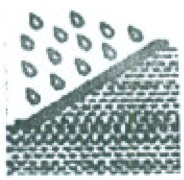
They are classified into following categories :

(1) Geo-Textiles (2) Geo-Grids (3) Geo-Membranes (4) Geo-Composites

There are a lot of functions of geo-synthetics some of them are being expressed below :

GENERAL FUNCTIONS OF GEO-SYNTHETICS

FUNCTION		PRODUCTS	DESCRIPTION
Filtration		geo-textiles, geo-composites	Allow the passages of fluids preventing the migration of soil particles
Drainage		Genets, geo-composites	Transport of fluids
Separation		geotextiles, geocomposites	Prevent the mixing of two different soils or materials
Protection		no woven geotextiles, genets, geocomposites	Avoid damages to a structure, a material or another geosynthetic.
Impermeabilization		Geomembranes geocomposites	Fluid barrier

Reinforcement of walls/steep slopes		monodirectional geogrids, woven geotextiles	Provide tensile forces in the soil mass.
Reinforcement of soft soil		bidirectional geogrids, geotextiles, geocomposites	Increase the bearing capacity
Reinforcement of Concrete, asphalt		bidirectional geogrids,	Provide tensile and fatigue resistance
Erosion control or surfacial stabilization		geomats, geocells, biomats, bionets,	Avoid the detachment and transport of soil particles by rain, runoff and wind; root enchorage

TYPES OF GEO-SYNTHETICS USED FOR ROAD CONSTRUCTION

Due to their durability, resistance against chemical and biological attack and high tensile strength (31-70 KN/m) Geo-Synthetics are widely used in pavement construction and maintenance. Generally following types of materials used in pavements :

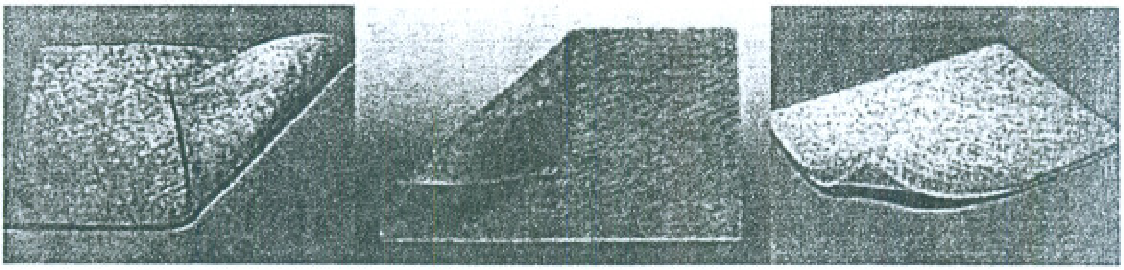
(1) Geo-Textiles (2) Geo-Girds (3) Geo-Nets (4) Geo-Membranes

(5) Geo-Composites

Let's have a look on each material stated above.

Geo-Textiles :

Modern Geo-textiles are permeable materials usually made from synthetic polymers like polypropylenes, polyesters, and polyethylenes etc, which do not decay under biological and chemical process. This makes them useful in roads construction and maintenance.



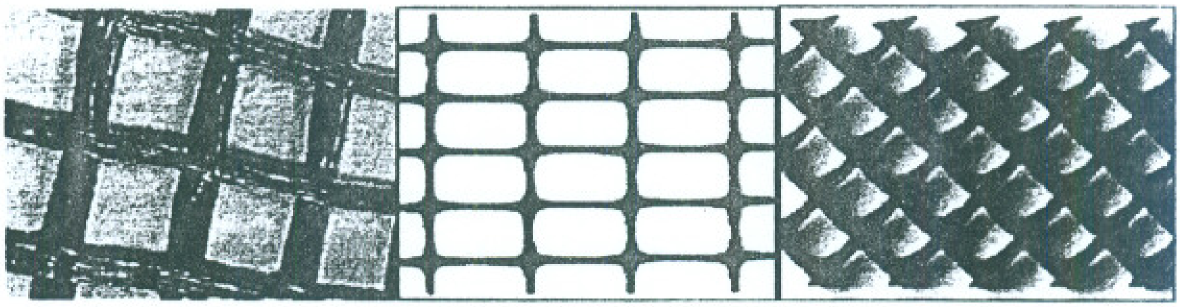
General Functions :

(1) Separations (2) Reinforcement (3) Filtration (4) Drainage

(5) Moisture Barrier

Geo-Grids / Geo-Nets :

These are interconnected polymer ribs which are configured in a net like structure. These are relatively high strength, high modulus, and low creep polymers with holes varying from 0.5 inch to 2 inch in size. Due to these properties they are extensively used in road constructions.



General Functions :

(1) Separations (2) Reinforcement

Geo-Membranes :

These are impermeable barriers used to contain various solids and liquids. The materials consist of thin sheets of rubber or plastic. The thickness depends the nature of their application and type of material used for their manufacturing.

General Functions :

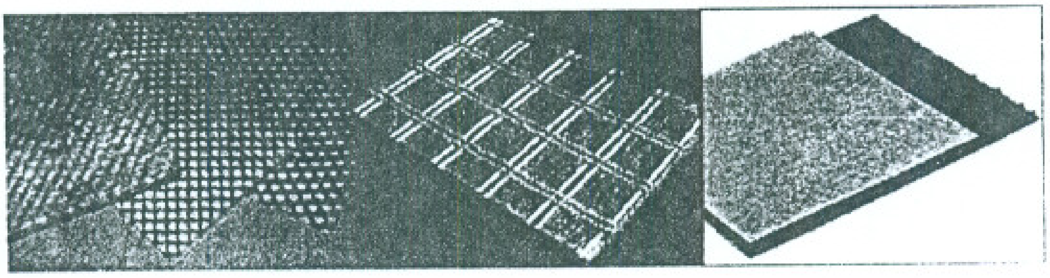
(1) As a water proofing layer (2) Seepage control

Geo-Composites :

Geo-Composites are the combination of any two of materials like :

Geo-Textiles + Geo-Nets OR Geo-Textiles + Geo-Membranes OR

Geo-Nets + Geo-Membranes etc.



General Functions :

(1) Separations (2) Reinforcement (3) Filtration (4) Drainage

(5) Moisture Barrier

They can be used for :

- Uniform distribution of loads
- Reduce the shearing resistance
- Semi-flexible foundation
- Geo-Composites having a combination of geo-textiles and geo-grids can be used for the protection of highway embankments.

Let's see how these materials used in roads construction and maintenance.

USE OF GEO-SYNTHETICS IN PAVEMENT CONSTRUCTION

Geo-synthetics are extensively used in roads construction industry like.

1. FOR SUB-SOIL REINFORCEMENT / STABILIZATION

Place of Installation :

Between natural soil and sub-grade.

Following materials are being used for soil reinforcement / stabilization.

Geo-Textiles :

These materials have high tensile strength and have high resistance to the erosion. If these materials are placed in multiple horizontal layers over the soft soil having low bearing capacity they will distribute the load evenly over the area, then the bearing capacity will increased up to a greater extent.

Advantage :

The use of geo-textiles materials is more preferable in the case of soil stabilization over conventional soil stabilization methods like :

(√) Stabilization procedure is much simple (√) Time saving (√) More economical

Geo-Textiles are also used for reinforcement of highway embankments due to following properties.

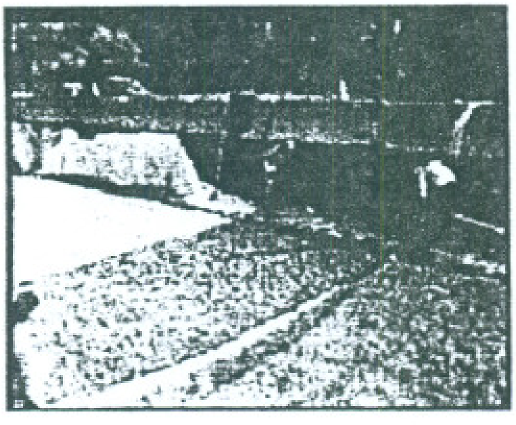
- Have greater friction against sliding
- Good drainage mechanism
- Higher resistance to erosion
- Higher immunity against chemical and biological attack.

Geo-Grids :

These materials have high tensile strength, high modulus of elasticity and have low creep values, due to these properties they are used for soil stabilization for high way construction.

Mechanism :

These materials having grid like structures due to which soil and aggregates interlock within geo-grid openings, which confine the soil and limit its relative displacements and increase the soil's shear resistance. The compaction may increase the degree of stabilization.



Geo-grid base reinforcement stiffens the aggregate base layer providing long-term support for the paved surface.

Advantage :

The use of geotextiles materials is more preferable in the case of soil stabilization over conventional soil stabilization methods like:

- Stabilization procedure is much simple
- Time saving
- More economical

(2) FOR THE REDUCTION OF BASE COURSE

Place of installation :

Between the base course and sub base.

Following materials are being used.

Geo-grids :

The base layer, made up from granular material, can sink in to foundation soil due to the heavy impact loads, due to which horizontal and vertical movements create that causing the ruts.

In traditional way this phenomena is cured by increasing the thickness of base course. If we use geo-grids between base and sub base then the settlement, sinking and rutting problems can be minimized due to which the thickness of base course can be reduced up to 40%.

(3) AS SEPERATOR BETWEEN SUB-GRADE AND BASE COURSE

Place of Installation :

Between sub-grade and base course.

Following material is used.

Geo-Textiles :

Generally access roads where sub-base course is not provided between sub-grade and base course, there are chance of rutting.

Mechanism :

Due to the moving loads fine particles move from base course to sub-grade and when meet with water a slurry type formation with in the aggregates due to which friction between particles reduces and thus causing rutting phenomena.

But this problem should be cured by using geo-textile materials which separates the two layers.

Advantages :

- Minimize the rutting
- Provide proper drainage for pavement
- Increase the life of pavement

(4) FOR SUBGRADE DEWATERING

Place of installation :

Below the sub grade.

Following material is generally used for the sub grade drainage.

Geo-Textiles :

Effectively dewatering require a very porous drainage media to accept seepage and a properly graded filter to piping. Geotextile materials have efficient drainage properties due to which are extensively used in this field in a simple and economical manner.

Mechanism :

A high ground water table often interface with the stability of sub grade soils due to which some soils swell or shrinks their W/T increases or decreases respectively.

Also, most soils are considerably weaker when they have high water contents or have not been drained prior to loading. It means that fluctuation in W / T can adversely affect the permanent structures founded on untrained soils.

Soil will only drained when it is provided by a smooth permeable zone that is efficiently provided by the use of geo-textile materials.

Advantages :

(√) Time saving as compared to traditional methods

(√) More economical (as much of excavation cost is being saved)

(√) Drainage is more effective as compared to routine methods

(√) Increase the life of pavement

SELECTION CRITERIA FOR GEO-SYNTHETICS

In early days when there were only a few materials available, design and selection was very simple. Today a large range of geo-synthetics is available due to which selection of a suitable material is very difficult.

For the design and selection of a certain geosynthetic following points should be considered.

- First adopt the conventional solutions, if they are impractical or uneconomical then come to the use of geo-synthetics
- Now study the properties and specifications of available geosynthetics
- Choose the best suitable material that fit for your requirements
- Compare the price of same materials with different manufactures
- Compare the quality of materials from various manufactures
- Availability of materials according to your requirements

Finally, as conventional construction procedure, careful field inspection during installation of geosynthetics is very important and necessary to increase durability and performance.

MANUFACTURERS OF GEO-SYNTHETIC MATERIALS

Following international companies are involved in manufacturing of these materials their names and website addresses are given below :

(1) Polyfelt Geo-Synthetics www.polyfelt.com

(2) Geo-fabrics Corporation www.geofabrics.com

(3) Tenax, Geo-synthetic Division www.tenax.net

(4) Marco Green International www.ms9.hinet.net

(5) Nilex Geo-Synthetics www.nilex.com

(6) Geo-Systems www.geosystems.com

(7) Texel Geo-Synthetics www.texel.qc.ca

(8) Terram Geo-Fabrics www.terram.com

Pakistani Companies involved in this business are

(1) National Engineers (2) Kris Geo-synthetics (3) National Scientific Corporation

(4) Silver Streak

CONCLUSION AND RECOMMENDATIONS:

From the above discussion following points have been concluded

(1) Use of Geo-synthetics materials is more economical as compared to conventional materials

(2) Use of Geo-synthetics materials is simpler as compared to traditional materials

(3) Their use is time saving and we can achieve required strength on exact time limitations

(4) They increase the life of highways

(5) With the help of these materials the maintenance process of highways is much easy and simple

(6) These materials must be used in highways construction for following purposes

- Sub-soil stabilization / Soil Improvement ♥ Filtration ♥ Drainage
- Embankment / Slope Stabilization
- Decrease the thickness of base coarse ♥ Separation
- Maintenance of Ruts and Cracks

Generally :

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