The TECH-MAG

(MAGAZINE OF THE ARTHUR HOPE COLLEGE OF TECHNOLOGY, COIMBATORE)

A. H. COLLEGE OF TECHNOLOGY

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"Suppose for instance, we are present at the building of a bridge: the bricklayers or masons have had their centering erected for them, and that centering was put together by a carpenter, who had the line of its curve traced for him by the architect: the masons are dexterously handling and fitting their bricks, or, by the help of machinery, carefully, adjusting stones which are numbered for their places. There is probably in their quickness of eye and readiness of hand something admirable: but this is not what I ask the reader to admire: not the carpentering, nor the bricklaying, nor anything that he can presently see and understand, but the choice of the curve, and the shaping of the numbered stones, and the appointment of that number; there were many things to be known and brought upon before these were decided. The man who chose the curve and numbered the stones, had to know the times and tides of the river, and the strength of its floods, and the height and flow of them, and the soil of the banks, and the endurance of it, and the weight of the stones he had to build with, and the kind of traffic that day by day would be carried on over his bridge, — all this especially, and all the great general laws of force and weight, and their working; and in the choice of the curve and numbering of stones are expressed not only his knowledge of these, but such ingenuity and firmness as he had, in applying special means to overcome the special difficulties about his bridge. There is no saying how much wit, how much depth of thought, how much fancy, presence of mind, courage, and fixed resolution there may have gone to the placing of a single stone of it"

John Ruskin, The Stones of Venice.

— *Courtesy:*

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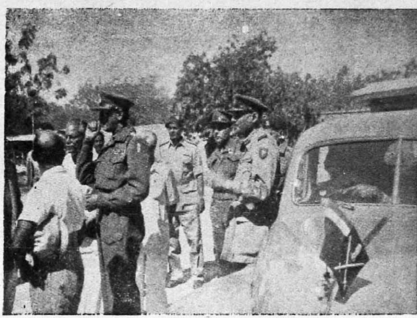

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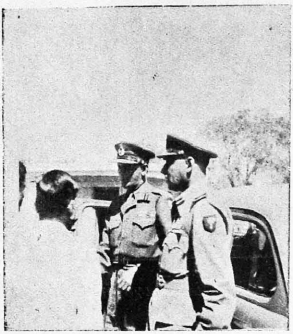

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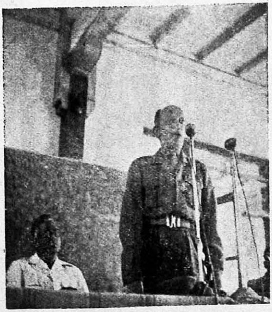

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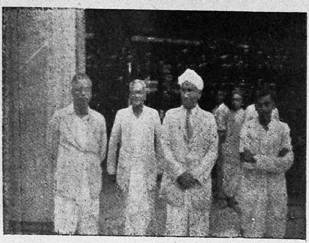

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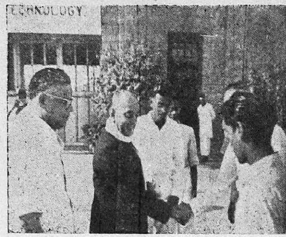

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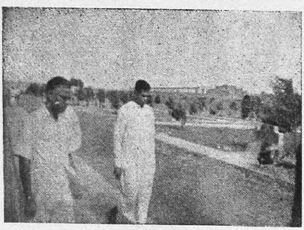

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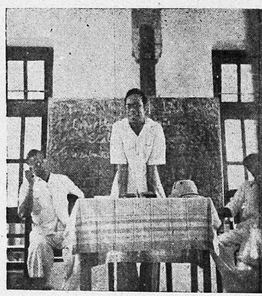

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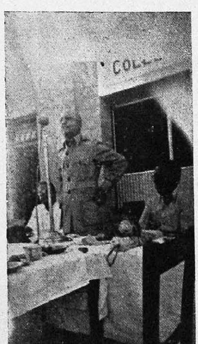

...A Major too

The

TECH-MAG

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Editorial

IT is our pleasant duty to present this, our second issue.

The warm welcome accorded to our first issue is highly encouraging. The pride of a humble achievement has inspired us in bringing out this issue. We hope this will prove as interesting as the last one. Being responsible for setting up precedents and standards for this Magazine as a permanent feature of a great institution, we have done our best with the earnest co-operation of the students as well as the members of the staff. Our sincere thanks are due to all those who have helped in making this issue what it is.

This year marks an important event in the history of our College. The first batch of students after graduating will be entering the world as engineers. Their record is a unique one; they have partaken of great experiences in their four years' stay here and have developed a sense of humour and perseverance to face any odds that may encounter them in their lives. No greater tribute is due to them than the fact that they are people who realised their responsibility of setting up traditions, and conducted themselves with dignity always and everywhere. We are sure that they would prove themselves worthy in every way and earn a great name for the College that trained them. May the Almighty bless them in all their endeavours in future!

Turning to the achievements of the year, our College has made very fast progress in equipment and it is now replete with all the laboratories and workshops functioning properly. Apart from the thrilling and unique experience of being students of a newly-started institution, it is a great delight to handle the latest of post-war machines in our workshops. The zeal with which work is carried on is the reason for our standard of performance at the University Examinations. We wish and hope it would be so for ever.

We are indebted to Dr. J. J. Rudra for his kind good wishes. We are thankful to our Patron Prof. A. Viswanath for his interest in our efforts and the interesting article written by Prof. Thackar and himself, which he has been pleased to contribute. Again, our sincere thanks are due to Prof. K. N. Ramanathan, Professor of Electrical Engineering, Vizag. College of Engineering, Cocanada, for his very valuable contribution, written specially for our Magazine, a product of intensive study for months together.

We wish the reader a good reading and hope the issue would be interesting enough.

Nursery Power Stations for Rural Development

Prof. A. VISWANATH, Arthur Hope College of Technology, Coimbatore

and

Prof. M. S. THACKAR, Indian Institute of Science, Bangalore

THE SUPPLY OF Electric Power is pre-requisite for embarking on any Development Programme, Rural, Agricultural, Cottage Industries and all Industrialisation Projects. The Central and Provincial Governments have already set themselves to tackle the problem of Power Development all over India. The ultimate aim of these projected plans is Power-grids spread all over the country with its transmission and distribution net-works to supply extensively cheap and abundant electrical energy.

Power Schemes to utilise fully the potentialities available in the country some of which are now being initiated and by the time all are fully completed, will involve a considerably long period. The supply from the Power-grids cannot be economically feasible till adequate developments, Rural and Agricultural have beforehand taken place and built up a load for it. The conditions of the vast majority of our rural population is such that they have neither the means nor can know the use and benefits of Electric Power. Most of our Cottage Industries are in a deplorable condition for want of motive power. In an Independent India it would be the first charge to improve the lot of rural population, develop agriculture and expand Cottage Industries. India, essentially an agricultural country, cannot feed herself. She cannot clothe herself and has also to depend on foreign countries for other necessities of life. In raising the economic standard of life of our people to a degree comparable to countries like U. K. and U. S. A., in the over-all schemes for developments, that of development of dormant and potential resources for Elecric Power is also of first importance. Pending completion of our major Electric Schemes, we cannot afford to ignore our rural population and leave them in their present dark conditions. At the same time we are counting on miracles to happen in safely assuming that the countryside would be ready to utilise electricity when the National Grid System comes into being. If we are thinking in these terms, sinking of large sums of money on extensive Power Projects is not justified. Apart from bettering the lot of the ryots by intensive Agricultural Development, expansion of Cottage Industries and other major and minor industrialisation projects of the country, we also want them to be ready to utilise the Power as soon as the large Power Projects come into being. The Power Development Schemes must therefore incorporate a phased programme which would help in the economic uplift of the people. We are therefore recommending an immediate practical way for supplying power for this

Programme of Rural Development by establishing all over the countryside small Power-Stations using Steam or Oil Prime Movers. These 'Nursery Power-Stations' will help to grow to manhood our large-scale plans. Prime Movers for these Nursery Power Stations can be graded in their capacities and standardised between the range 50 K. W. to 500 K. W. Each Nursery Station would radiate power to cover a maximum of 10 to 12 miles distribution net work so designed and constructed as to readily merge into ultimate grid net work. For this purpose we define a single or a group of villages on a predetermined basis of minimum population. It would be possible in a large number of cases to provide the required head of water for installation of water turbines, without construction of long acqueducts and thus minimising Civil Engineering work and its cost. Apart from demand for Steam and Oil Prime Movers there will be created a demand for water turbines which are cheap and easily manufactured.

In the installation of Nursery Power Plants, serious thought has to be given to 'Package Units'. They could be built to be readily transported on rails and brought into use, to establish a new Station or augment existing ones. Such sets could be truck mounted for transport to countryside inaccessible to Railways. The completion of our large Power Schemes as stated before is not a day's job. The Nursery Power Stations will run for a number of years before they are finally closed down and by the time they come nearer to be closed down would have served their purpose and useful period of life.

The Prime Movers and the electrical machinery manufacturing industries of the country will receive a considerable impetus and will start simultaneously and in step on a sound basis.

To sum up, Nursery Power Stations serve as a strong and also as an effective weapon for :—

1. Rural and Agricultural Development and Development of Cottage Industries, thus helping to ameliorate the economic conditions.
2. The load building essential for purposes of All India Grid Power Supply.
3. An immediate impetus for an intensive development of manufacture of Prime Movers and Electrical Machines in this country.

Alpha, Beta and Zero Components

(and their application to Power System Calculations)

by

K. N. RAMANATHAN, B.E., M.SC., A.M.I.E.

Summary :— In this article, a brief description of a new system of components, called the α, β, o components is given, and their relation to the well known Symmetrical Components is derived. The method of obtaining the α, β, o equivalent circuits for setting up in A. C. Network Analyser is given.

List of Symbols :

a, b, c.	=	The three phases of a star connected three phase system.
A, B, C.	=	The three phases of a delta connected three phase system.
V_a, V_b, V_c.	=	Applied phase voltage vectors.
E_a, E_b, E_c.	=	Generated phase voltage vectors.
V_{a1}, V_{a2}, V_{a0}.	=	Positive, Negative and Zero Sequence voltage vectors.
V_{α}, V_{β}, V_{o}.	=	α, β, o voltage vectors.
I_a, I_b, I_c.	=	Phase current vectors.
I_{a1}, I_{a2}, I_{a0}.	=	Positive, Negative and Zero Sequence current vectors.
I_{α}, I_{β}, I_{o}.	=	α, β, o current vectors.
Z_{aa}, Z_{bb}, Z_{cc}.	=	Self impedances of phases.
$Z_{\alpha\alpha}$, $Z_{\beta\beta}$, Z_{oo}.	=	α, β, o self impedances.
Z_{a1}, Z_{a2}, Z_{a0}.	=	Positive, Negative and Zero Sequence self impedances.
Z_{ab}, Z_{ca}, $Z_{\alpha\beta}$, $Z_{o\alpha}$ etc.,	=	Mutual impedances.
v_{α}, v_{β}, v_{o}, v_a etc.,	=	Voltage drops.
j	=	Operator rotating a vector in the anti-clockwise direction by 90°.
h	=	Operator rotating a vector in the anti-clockwise direction by 120°.

Introduction:

The problems facing the Power Engineer, can generally be classified under the following heads:

(a) Problems that can be solved fairly easily by well-known methods, such as the method of Symmetrical Components.

(b) Problems which are capable of analytical solution, but requiring an immense amount of labour, and

(c) Problems that have no available analytical solution.

The application of the method of Symmetrical Components, use of mechanical and electrical calculating devices, laboratory tests on miniature transmission systems and actual field tests are the methods available at the present time.

There are however many problems, which allow a much simpler solution, by employing a new set of components, called the Alpha, Beta and Zero Components. These are related to the well-known Symmetrical Components, and can be derived from them. The conception of these components is not new, and a method of employing such components, was suggested as early as 1917 by Dr. W. W. Lewis. Since then, a number of papers have been published on the subject, and listed in the bibliography at the end, which should be read for a comprehensive understanding of the subject.

The purpose of this article is to present in a simple form, this new system of components, and show how to build up equivalent circuits, which facilitate the solution of many complicated problems. Alpha, Beta, Zero Components present a point of view, which is helpful in visualising a problem, even though the final solution is obtained by other methods.

Alpha, Beta, Zero Components of Three Phase Systems:

With phase 'a' as reference, the $\propto$, β, o components of currents and voltages in a three phase system can be defined as follows:—

$\propto$ components of current enter by phase 'a' and return one half through phase 'b' and one half through phase 'c'. $\propto$ components of currents in phases 'b' and 'c' are equal in magnitude, but opposite in sign, and have half the magnitude of the $\propto$ component in phase 'a'.

β components of current are currents circulating in phases 'b' and 'c' only, and are zero in phase 'a'. β components of currents in phases 'b' and 'c' are equal in magnitude, but opposite in sign.

o components are the same as the zero sequence currents of symmetrical component theory.

In three phase systems, sinusoidal voltages and currents are generally represented by three coplanar vectors such as V_a, V_b, and V_c, revolving with an angular velocity $\omega = 2\pi f$. Since the angles between the vectors are fixed, they can be replaced by three new vectors V_1, V_2 and V_3, where,

$$V_a = c_{11}V_1 + c_{12}V_2 + c_{13}V_3 \qquad (1)$$

$$V_b = c_{21}V_1 + c_{22}V_2 + c_{23}V_3 \qquad (2)$$

$$V_c = c_{31}V_1 + c_{32}V_2 + c_{33}V_3 \qquad (3)$$

and the co-efficients c_{11}, c_{12} etc., are arbitrary and constant, except for the condition, that the determinants made up of the co-efficients is not zero. Putting, $V_1 = V_\alpha$; $V_2 = V_\beta$ and $V_3 = V_o$ in the above equations, the constant co-efficients required to express the phase voltages V_a, V_b and V_c in terms of their $\propto$, β, o components are $c_{11} = 1$; $c_{21} = -\frac{1}{2}$; $c_{31} = -\frac{1}{2}$; $c_{12} = 0$; $c_{22} = \sqrt{\frac{3}{2}}$; $c_{32} = -\sqrt{\frac{3}{2}}$; $c_{13} = c_{23} = c_{33} = 1$. Substituting these values in equations (1) to (3).

$$V_a = V_\propto + V_o \qquad (4).$$

$$V_b = -\tfrac{1}{2}V_\propto + \frac{\sqrt{3}}{2}V_\beta + V_o \qquad (5).$$

$$V_c = -\tfrac{1}{2}V_\propto - \frac{\sqrt{3}}{2}V_\beta + V_o \qquad (6).$$

Solving the above simultaneous equations, we get

$$V_\propto = \tfrac{2}{3}\left(V_a - \frac{V_b + V_c}{2}\right) \qquad (7).$$

$$V_\beta = \frac{1}{\sqrt{3}}(V_b - V_c) \qquad (8).$$

$$V_o = \tfrac{1}{3}(V_a + V_b + V_c) \qquad (9).$$

In the same manner, the equations for currents are,

$$I_a = I_\propto + I_o \qquad (10).$$

$$I_b = -\tfrac{1}{2} I_\propto + \frac{\sqrt{3}}{2} I_\beta + I_o \qquad (11).$$

$$I_c = -\tfrac{1}{2}I_\propto - \frac{\sqrt{3}}{2}I_\beta + I_o \qquad (12).$$

$$I_{\propto} = \tfrac{2}{3}\left(I_a - \frac{I_b + I_c}{2}\right) \qquad (13).$$

$$I_{\beta} = \frac{1}{\sqrt{3}}\left(I_b - I_c\right) \qquad (14).$$

$$I_o = \tfrac{1}{3}\,(I_a + I_b + I_c) \qquad (15).$$

The above equations, express any set of three voltage or current vectors of a three phase system, in terms of Alpha, Beta and Zero components. Generated voltages in a synchronous machine are obtained by substituting the generated voltages E_a, E_b, E_c etc., for V_a, V_b, V_c etc., in equations (7) to (9) as shown below:

$$E_{\propto} = \tfrac{2}{3}\left(E_a - \frac{E_b + E_c}{2}\right) \qquad (16).$$

$$E_{\beta} = \frac{1}{\sqrt{3}}\left(E_b - E_c\right) \qquad (17).$$

$$E_o = \tfrac{1}{3}\,(E_a + E_b + E_c) \qquad (18).$$

In a balanced three phase system, $E_b = h^2E_a$ and $E_c = hE_a$. Therefore,

$$E_{\propto} = E_a \qquad (19).$$

$$E_{\beta} = -jE_a \qquad (20).$$

$$E_o = 0 \qquad (21).$$

It will be seen from the above equations, that the generated voltage in the Alpha network is E_a, while that in the Beta network is also equal to E_a, but rotated backwards by 90°. There is no voltage in the Zero network. Similarly,

$$I_{\propto} = I_a \qquad (22).$$

$$I_{\beta} = -jI_a \qquad (23).$$

$$I_o = 0 \qquad (24).$$

Alpha, Beta, Zero Networks:

In setting up networks for the $\propto$, β, o components, common references are necessary. In a star connected system, $\propto$ and β voltages are referred to neutral, since the neutral is a zero point of potential for them. The terms "voltage to neutral", and "voltage to ground", are interchangeable as in the case of positive and negative sequence components.

Consider a balanced, symmetrical three phase system shown in Fig: 1, having equal self impedances in the three phases.

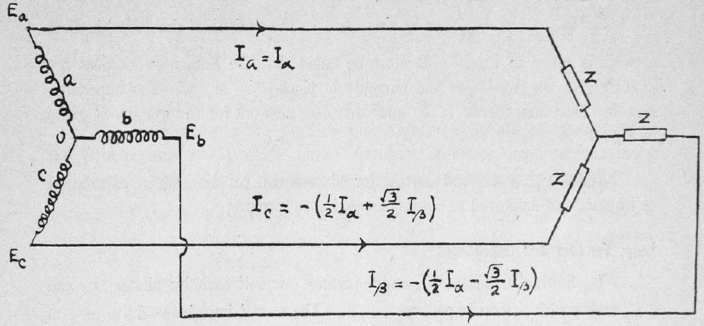
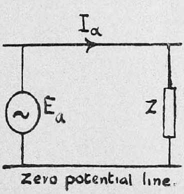


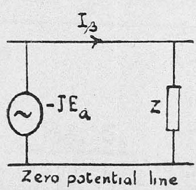
Fig. 1. α and β Currents in balanced Systems.

Taking the α component of the current first, by definition, I_α flows in phase 'a' and returns one half each via phases 'b' and 'c'. The current flows in a closed loop circuit, having an equivalent loop impedance $= \frac{3}{2}$ Z, and a voltage round the circuit $= \frac{3}{2} E_a$. The current in phase 'a' is

$$I_a = I_\alpha = \frac{\frac{3}{2}E_a}{\frac{3}{2}Z} = \frac{E_a}{Z}$$

The equivalent circuit for phase 'a' in the Alpha network is given in fig. 2. The β currents flow into phase 'b' and return through phase 'c'. The voltage driving this





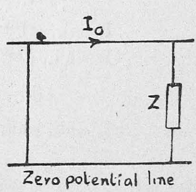


Fig. 2. α Network. Fig. 3. β Network. Fig. 4. O Network

current is $-j\sqrt{3}\,E_a$. The impedance of the circuit is 2Z. The β current flowing in phase 'b' is

$\frac{\sqrt{3}}{2} I_\beta = -j \frac{\sqrt{3}\, E_a}{2Z}$ or $I_\beta = -j \frac{E_a}{Z}$. The equivalent circuit for the Beta network is given in Fig. 3. It must be noted that the Beta network does not directly give the β voltages and currents in phases 'b' or 'c'. The impedance met by Zero components is Z, and the Zero network for the system is given in Fig: 4.

The α, β, o self and mutual impedances can be obtained by calculation or by test, and employed to obtain the equivalent circuits.

Loop, Voltages and Impedances:

I_α flowing in phase 'a', and returning one half each by phases 'b' and 'c', meets with a loop impedance $= \frac{3}{2} Z$. The α self impedance $Z_{\alpha\alpha} = \frac{2}{3}$ of the loop impedance. Similarly, I_β flowing in phases 'b' and 'c' meets an impedance equal to 2Z. The β self impedance $Z_{\beta\beta}$ is half the loop impedance. The above apply to symmetrical circuits only.

Relation Between α, β, o and Symmetrical Components:

It is well-known, that the voltage and current vectors V_a, V_b, V_c, I_a, I_b and I_c of a three phase system can be expressed in terms of their symmetrical components, by

$$V_a = (V_{a1} + V_{a2}) + V_{a0} \tag{25}$$

$$V_b = h^2 V_{a1} + h V_{a2} + V_{a0}$$

$$= -\tfrac{1}{2}(V_{a1} + V_{a2}) - j\frac{\sqrt{3}}{2}(V_{a1} - V_{a2}) + V_{a0} \tag{26}$$

$$V_c = h V_{a1} + h^2 V_{a2} + V_{a0}$$

$$= -\tfrac{1}{2}(V_{a1} + V_{a2}) + j\frac{\sqrt{3}}{2}(V_{a1} - V_{a2}) + V_{a0} \tag{27}$$

$$I_a = (I_{a1} + I_{a2}) + I_{a0} \tag{28}$$

$$I_b = h^2 I_{a1} + h I_{a2} + I_{a0}$$

$$= -\tfrac{1}{2}(I_{a1} + I_{a2}) - j\frac{\sqrt{3}}{2}(I_{a1} - I_{a2}) + I_{a0} \tag{29}$$

$$I_c = h I_{a1} + h^2 I_{a2} + I_{a0}$$

$$= -\tfrac{1}{2}(I_{a1} + I_{a2}) + j\frac{\sqrt{3}}{2}(I_{a1} - I_{a2}) + I_{a0} \tag{30}$$

Comparing the above with equations (4) to (6) and (10) to (12), it can be seen that,

$$V_\alpha = (V_{a1} + V_{a2}) \tag{31}$$

$$V_\beta = -j(V_{a1} - V_{a2}) \tag{32}$$

$$V_o = V_{a0} \tag{33}$$

$$I_\alpha = (I_{a_1} + I_{a_2}) \tag{34}$$

$$I_\beta = -j\,(I_{a_1} - I_{a_2}) \tag{35}$$

$$I_o = I_{a_0} \tag{36}$$

The $\propto$ components are positive plus negative sequence components, and the β components are positive minus negative sequence components rotated backwards by 90°. Solving the above six equations and re-arranging, we get

$$V_{a_1} = \tfrac{1}{2}\,(V_\alpha + jV_\beta) \tag{37}$$

$$V_{a_2} = \tfrac{1}{2}\,(V_\alpha - jV_\beta) \tag{38}$$

$$V_{a_0} = V_o \tag{39}$$

$$I_{a_1} = \tfrac{1}{2}\,(I_\alpha + jI_\beta) \tag{40}$$

$$I_{a_2} = \tfrac{1}{2}\,(I_\alpha - jI_\beta) \tag{41}$$

$$I_{a_0} = I_o \tag{42}$$

Self and Mutual Impedances in Terms of $\propto$, β, o Components:

Referring to Fig: 5, let the $\propto$, β, o components of voltages to ground or neutral at M and N be V_α, V_β, V_o and $V_\alpha{}^1$, $V_\beta{}^1$, $V_o{}^1$ respectively. Let I_α, I_β, I_o be the currents flowing from M to N. The equations for the voltage drops v_α, v_β, v_o between M and N are

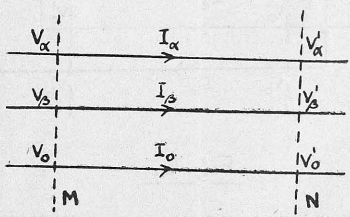


Fig. 5.

$$v_\alpha = V_\alpha - V_\alpha{}^1 = I_\alpha Z_{\alpha\alpha} + I_\beta Z_{\alpha\beta} + I_o Z_{\alpha o} \tag{43}$$

$$v_\beta = V_\beta - V_\beta{}^1 = I_\alpha Z_{\beta\alpha} + I_\beta Z_{\beta\beta} + I_o Z_{\beta o} \tag{44}$$

$$v_o = V_o - V_o{}^1 = I_\alpha Z_{o\alpha} + I_\beta Z_{o\beta} + I_o Z_{oo} \tag{45}$$

where, $Z_{\alpha\alpha}$, $Z_{\beta\beta}$, Z_{oo} are self impedances in the α, β, o networks and Z's with unequal subscripts, the mutual impedances.

If there is no Zero sequence current, no voltages would be induced in the α, β networks by I_o and $Z_{\alpha o} = Z_{\beta o} = o$, and $Z_{oo} = \alpha$. The equations then become,

$$v_\alpha = I_\alpha Z_{\alpha\alpha} + I_\beta Z_{\alpha\beta} \qquad (46)$$

$$v_\beta = I_\alpha Z_{\beta\alpha} + I_\beta Z_{\beta\beta} \qquad (47)$$

$$v_o = I_\alpha Z_{o\alpha} + I_\beta Z_{o\beta} + o. \alpha \qquad (48)$$

The last equation appears indeterminate, but can be solved from a solved from a knowledge of the operating conditions.

Consider the three phase circuit of Fig: 6, with a return path for o currents, and without internal voltages between P and Q. The voltage drops v_a,

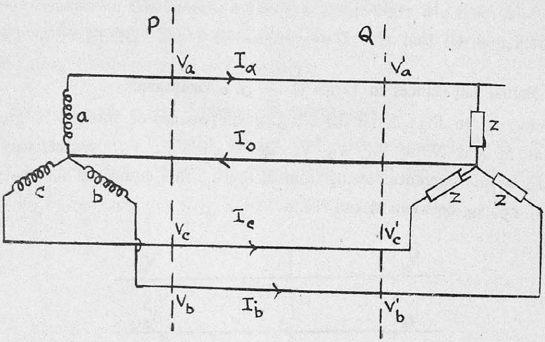


Fig. 6.

v_b, v_c in the direction of flow, between the points P and Q are

$$v_a = I_a Z_{aa} + I_b Z_{ab} + I_c Z_{ac} \qquad (49)$$

$$v_b = I_a Z_{ba} + I_b Z_{bb} + I_c Z_{bc} \qquad (50)$$

$$v_c = I_a Z_{ca} + I_b Z_{cb} + I_c Z_{cc} \qquad (51)$$

Replacing I_a, I_b and I_c by their α, β, o components from equations (10) to (12) and substituting these equations in (7), (8) and (9), v_α, v_β, v_o are expressed in terms of I_α, I_β, I_o. Equating the co-efficients of I_α, I_β and I_o to the co-efficients in equations (43), (44) and (45), the α, β, o self and mutual impedances are obtained in terms of phase impedances and are

$$Z_{\alpha\alpha} = \tfrac{2}{3}\left[Z_{aa} + \frac{Z_{bb} + Z_{cc}}{4} - (Z_{ab} + Z_{ac} - \frac{Z_{bc}}{2}\right] \quad (52)$$

$$Z_{\beta\beta} = \tfrac{1}{2}\left[Z_{bb} + Z_{cc} - 2Z_{bc}\right] \quad (53)$$

$$Z_{\alpha\beta} = Z_{\beta\alpha} = \frac{1}{2\sqrt{3}}\left[Z_{cc} - Z_{bb} + 2\,(Z_{ab} - Z_{ac})\right] \quad (54)$$

$$Z_{\alpha o} = 2Z_{o\alpha} = \tfrac{1}{3}\left[2Z_{aa} - Z_{bb} - Z_{cc} + (Z_{ab} + Z_{ac} - 2Z_{bc})\right] \quad (55)$$

$$Z_{\beta o} = 2Z_{o\beta} = \frac{1}{\sqrt{3}}\left[Z_{bb} - Z_{cc} + (Z_{ab} - Z_{ac})\right] \quad (56)$$

$$Z_{oo} = \tfrac{1}{3}\left[Z_{aa} + Z_{bb} + Z_{cc} + 2\,(Z_{ab} + Z_{ac} + Z_{bc})\right] \quad (57)$$

In a symmetrical three phase system, where all self impedances are equal to Z_{aa} and all mutual impedances equal to Z_{aa}, the above equations become,

$$Z_{\alpha\alpha} = Z_{\beta\beta} = Z_{aa} - Z_{ab} \quad (58)$$

$$Z_{oo} = Z_{aa} + 2Z_{ab} \quad (59)$$

$$Z_{\alpha\beta} = Z_{\beta\alpha} = Z_{\beta o} = Z_{o\beta} = Z_{\alpha o} = Z_{o\alpha} = 0 \quad (60)$$

In a three phase self impedance circuit, with no mutual impedances, let the phase impedances be Z_a, Z_b and Z_c. The $\propto$, β, o self and mutual impedances for such a circuit are.

$$Z_{\alpha\alpha} = \tfrac{2}{3}\left(Z_a + \frac{Z_b + Z_c}{4}\right) \quad (61)$$

$$Z_{\beta\beta} = \frac{Z_b + Z_c}{2} \quad (62)$$

$$Z_{oo} = \frac{Z_a + Z_b + Z_c}{3} \quad (63)$$

$$Z_{\alpha\beta} = Z_{\beta\propto} = \frac{Z_c - Z_b}{2\sqrt{3}} \quad (64)$$

$$Z_{\alpha o} = 2Z_{o\alpha} = \frac{2Z_a - Z_b - Z_c}{3} = 2\,(Z_a - Z_{\alpha\alpha}) \quad (65)$$

$$Z_{\beta o} = 2Z_{o\beta} = \frac{Z_b - Z_c}{\sqrt{3}} \quad (66)$$

In a symmetrical self-impedance circuit where

$Z_a = Z_b = Z_c = Z$, $Z_{\alpha\alpha} = Z_{\beta\beta} = Z_{oo} = Z$, and

$Z_{\alpha\beta} = Z_{\alpha o} = Z_{\beta o} = Z_{o\alpha} = Z_{o\beta} = 0$.

The $\propto$, β, o self and mutual impedances given by equations (52) to (66) apply to star-connected circuits with earthed neutral, if I_α, I_β, I_o are the components of currents flowing into the circuit and v_α, v_β, v_o the components of voltages to neutral at the circuit terminals. Z_{oo} in these equations is the O self-impedance between circuit terminals and neutral. If the neutral is grounded through an impedance Z_n, and Z_{oo} replaced by $(Z_{oo} + 3Z_n)$, v_o will be referred to ground.

If the neutral is ungrounded, equations (46) to (48) will apply. The voltage at neutral of an isolated star-connected circuit can be evaluated as follows. $\propto$, β currents flowing in the circuit produce a voltage drop v_o between circuit terminals T and neutral N, where

$$v_o = I_\alpha Z_{o\alpha} + I_\beta Z_{o\beta} \qquad (67)$$

If the voltage at T is $V_{O(T)}$, the voltage V_N at N is

$$V_N = V_{O(T)} \mp v_O = V_{O(T)} - I_\alpha Z_{o\alpha} - I_\beta Z_{o\beta} \qquad (68)$$

$V_{O(T)}$ can be evaluated when the O impedance diagram and operating conditions are given. If the O voltage at T is Zero, the voltage at neutral is

$$V_N = - I_\alpha Z_{o\alpha} \mp I_\beta Z_{o\beta} \qquad (69)$$

where $Z_{o\alpha}$ and $Z_{o\beta}$ are defined from equations (52) to (63). If $Z_b = Z_c$; $Z_{o\beta} = O$. Then if $V_{O(T)} = O$.

$$V_N = - I_\alpha Z_{o\alpha} \qquad (70)$$

Problem: Balanced three phase voltages are applied from an earthed source, through Zero impedances to the terminals of a circuit consisting of 3 condensers, connected in ungrounded star. The three capacitive impedances are $-Jx$, $-Jy$ and $-Jy$. Determine the currents in the three phases and the voltage to ground from the star-point of the condensers.

Solution:

Let $Z_a = -Jx$; $Z_b = Z_c = -Jy$.

E_a = Voltage applied to phase a

The applied $\propto$ Voltage is E_a. The $\propto$ impedance is $\frac{2}{3}\left(Z_a + \frac{Z_b}{2}\right)$

$$I_a = I_\alpha = \frac{E_a}{\frac{2}{3}\left(Z_a + \frac{Z_b}{2}\right)} = \frac{3E_a}{2Z_a + Z_b} = J\,\frac{3E_a}{2x + y}$$

The applied β voltage is $-JE_a$. The β impedance $= Z_b$.

$$I_\beta = \frac{-JE_a}{Z_b} = \frac{E_a}{y}$$

$$I_b = -\tfrac{1}{2} I_\alpha + \frac{\sqrt{3}}{2} I_\beta = E_a\left[\frac{\sqrt{3}}{2y} - J\,\frac{3}{4x + 2y}\right]$$

$$I_c = -\tfrac{1}{2} I_\alpha - \frac{\sqrt{3}}{2} I_\beta = -E_a \left[\frac{\sqrt{3}}{2y} + J\frac{3}{4x + 2y}\right]$$

The voltage V_n at the neutral is

$$V_n = E_a - I_a Z_a$$

$$= E_a \frac{Z_b - Z_a}{2Z_a + Z_b} = E_a \left(\frac{y - x}{2x + y}\right)$$

Alpha, Beta, Zero, Equivalent Circuits:

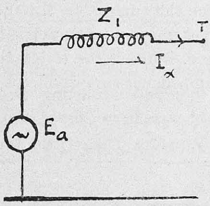
(a) *Synchronous Machines with equal positive and negative sequence Impedances:*— In such machines with no mutual impedance between the sequence networks, the α, β, o self and mutual impedances can be shown to be

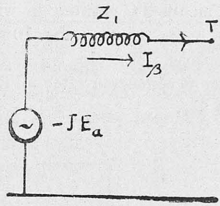
$$Z_{\alpha\alpha} = Z_{\beta\beta} = Z_{a1} = Z_1 \quad (71)$$

$$Z_{oo} = Z_{oo} = Z_{ao} = Z_o \quad (72)$$

$$Z_{\alpha\beta} = Z_{\beta\alpha} = Z_{\alpha o} = Z_{o\alpha} = Z_{\beta o} = Z_{o\beta} = 0. \quad (73)$$

where Z_1, Z_2 and Z_o are the customary positive, negative and zero sequence self-impedances without mutual impedances. With balanced induced voltage in the machine, the equivalent circuits for the α, β, o networks of the synchronous machine are given in Figs. (7) (8) and (9).





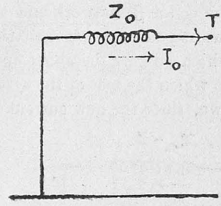


Fig. 7. α Circuit. Fig. 8. β Circuit. Fig. 9. O Circuit.

The points T in the figures are the terminals to which the equivalent α, β, o circuits of the rest of the system are connected.

(b) *Synchronous Machines with unequal positive and negative sequence impedances:* When $Z_1 \neq Z_2$ it can be shown that when there are no mutual impedances between the sequence networks.

$$Z_{\alpha\alpha} = Z_{\beta\beta} = \tfrac{1}{2}(Z_1 + Z_2) \quad (74)$$

$$Z_{oo} = Z_o. \quad (75)$$

$$Z_{\alpha\beta} = -Z_{\beta\alpha} = J\tfrac{1}{2}(Z_1 - Z_2) \qquad (76)$$

$$Z_{\alpha o} = Z_{o\alpha} = Z_{\beta o} = Z_{o\beta} = 0. \qquad (77)$$

It will be seen from the above equations, that though there is no mutual coupling with the O network, the $\propto$ and β networks are coupled through a mutual impedance which is not the same in either direction. As such the application of the $\propto$, β, o components in the solution of such circuits is complicated when compared with symmetrical components.

(c) *Three Phase unsymmetrical Static Circuits:* Referring to equations (52) to (57) and (61) to (66) it can be seen that $Z_{\alpha\beta} = Z_{\beta\alpha}$; $Z_{\alpha o} = 2Z_{o\alpha}$ and $Z_{\beta o} = 2Z_{o\beta}$. Applying these values, equations (43) to (45) can be written in the following form.

$$v_\alpha = I_\alpha Z_{\alpha\alpha} + I_\beta Z_{\alpha\beta} + (2I_o)\frac{Z_{\alpha o}}{2} \qquad (78)$$

$$v_\beta = I_\alpha Z_{\beta\alpha} + I_\beta Z_{\beta\beta} + (2I_o)\frac{Z_{\beta o}}{2} \qquad (79)$$

$$v_o = I_\alpha Z_{o\alpha} + I_\beta Z_{o\beta} + (2I_o)\frac{Z_{oo}}{2} \qquad (80)$$

The above equations are more suitable than equations (43) to (45) in cases where $Z_{\alpha o} = 2Z_{o\alpha}$ and $Z_{\beta o} = 2Z_{o\beta}$ and give reciprocal mutual coupling between the $\propto$ (or β) network and a modified O network in which the current is $2I_o$ and the impedances one half the actual values. Fig. 10 gives the equivalent circuit which satisfies the above equations. M_α, M_β, N_α, N_β etc. indicate the terminals to which the rest of the system is connected after all O impedances are divided by two, since the new current is $2I_o$.

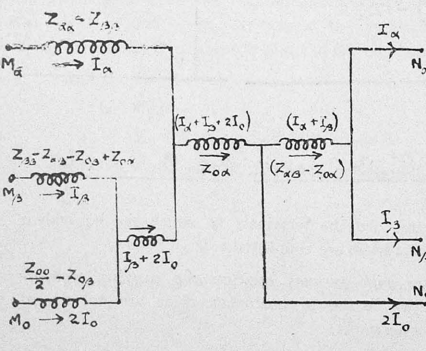


Fig. 10 (a).

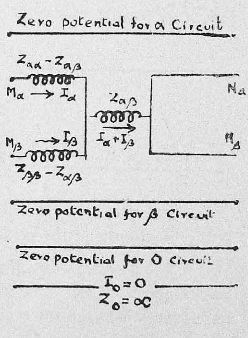


Fig. 10 (b).

The equivalent circuit can be tested for self and mutual Impedances by opening the various parts of the network suitably. If a net-work analyser is employed, mutual couplings can be obtained by means of transformers or by direct connections.

Short Circuits on Power Systems:

The relations between the α, β, o components of phase voltages at the fault to ground or neutral, and between I_α, I_β and I_o, the α, β, o fault currents, can be calculated as shown below, where the particular case of a double line to ground fault on the two phases 'a' and 'b' is worked out. In an unsymmetrical fault of this kind, the conditions at the fault are:—

$$V_a = V_b = 0 \, ; I_c = 0.$$

Substituting these values in equations (4), (7), (8) and (9) and (12)

$$V_\alpha = -V_o = \frac{V_\beta}{\sqrt{3}}$$

$$I_\alpha = -\sqrt{3}\, I_\beta + 2\, I_o$$

The relations between voltages and currents are worked out in a similar manner for different kinds of fault conditions and the results given in the form of a table below.

TABLE I.

Case	Type of Fault	Lines involved	Equations of Voltages at Fault	Equations of Currents at Fault
A — 1.	Three-phase	a, b, c	$V_\alpha = 0;\ V_\beta = 0$	$I_o = 0$
2.		a, b, c and ground	$V_\alpha = 0;\ V_\beta = 0;$ $V_o = 0$	
B — 1.	Line-to-ground	a and ground	$V_\alpha = -V_o$	$I_\beta = 0;$ $I_\alpha = 2I_o$
2.	Line-to-ground	b and ground	$V_\alpha = \sqrt{3}\, V_\beta + 2V_o$	$I_\alpha = -\frac{I_\beta}{\sqrt{3}};$ $I_\alpha = -I_o$
3.	Line-to-ground	c and ground	$V_\alpha = -\sqrt{3}\, V_\beta + 2V_o$	$I_\alpha = -\frac{I_\beta}{\sqrt{3}};$ $I_\alpha = -I_o$
C — 1.	Line-to-line	b and c	$V_\beta = 0$	$I_\alpha = 0;\ I_o = 0.$
2.	Line-to-line	a and b	$V_\alpha = \frac{V_\beta}{\sqrt{3}}$	$I_\alpha = -\sqrt{3}\, I_\beta;$ $I_o = 0.$

Case	Type of Fault	Lines involved	Equations of Voltages at Fault	Equations of Currents at Fault
3.	Line-to-line	a and c	$V_\alpha = -\frac{V_\beta}{\sqrt{3}}$	$I_\alpha = \sqrt{3}\, I_\beta$; $I_o = 0$
D — 1.	Two line-to-ground	b, c and ground	$V_\beta = 0$; $V_\alpha = 2V_o$	$I_\alpha = -I_o$
2.	Two line-to-ground	a, b and ground	$V_\alpha = \frac{V_\beta}{\sqrt{3}} = V_\alpha = -V_c$	$I_\alpha = -\sqrt{3}\, I_\beta + 2I_o$
3.	Two line-to-ground	a, c and ground	$V_\alpha = -\frac{V_\beta}{\sqrt{3}}$; $V = -V_\alpha$	$I_\alpha = \sqrt{3}\, I_\beta + 2I_o$

α, β, o Networks to Represent Short Circuits:

Fig. 11 gives the α, β, o networks satisfying the fault conditions given in Table (I) case A(1) above. The fault in each circuit is at the point F, and the unsymmetrical circuit between P and Q. Mutual impedances may be present between the circuits, but are omitted here.

Case A (1).

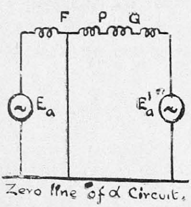


Fig. 11 (a)

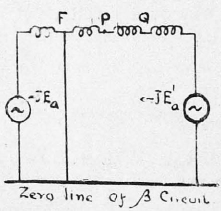


Fig. 11 (b)

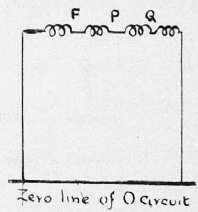


Fig. 11 (c)

The circuits represent a simultaneous fault condition to ground, from the phases 'a', 'b', and 'c', with two synchronous machines connected to the far ends of the system. E_a and E'_a are the generated voltages of the two generators in phase 'a'.

Case A (2) is similar to Case A (1), except that the point F in the Zero network has to be earthed to the Zero potential line.

Case B (1) is represented by the network of Fig; 12.

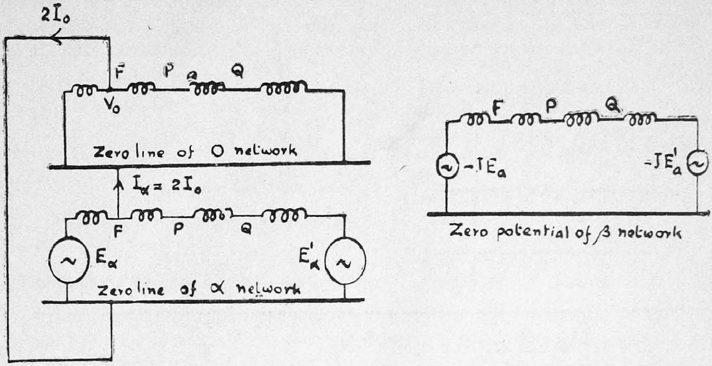


Fig. 12. Case B (1).

Case B (2) is satisfied by network of Fig. 13. Networks for the other cases in Table I, can be drawn in a similar manner.

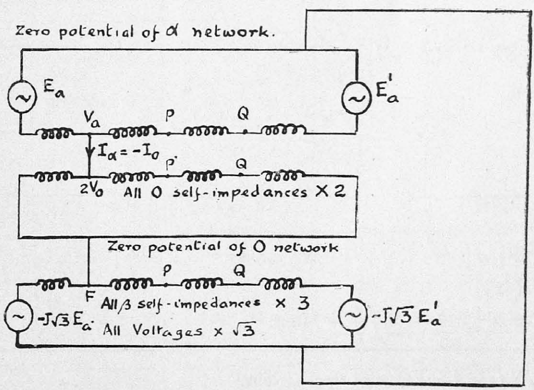


Fig. 13. Case B (2).

Open Circuits in Power Systems:

Fig. 14, shows a three phase system, with one open conductor 'b'. Let v and I' with the necessary subscripts, represent the voltage drops between P and Q and the currents flowing across the opening. Conditions at the fault are

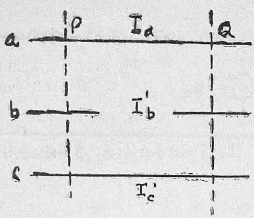


Fig. 14.

$v_a = v_c = 0$

$I_b = 0$

Substituting these relations in equations (4), (6) and (11),

$$v\alpha = -\frac{v\beta}{\sqrt{3}} = -vo$$

$$I'\alpha = +\sqrt{3}I'_\beta - 2I'_o = 0$$

Similarly, other conditions of open circuit are calculated and given in Table II.

TABLE II.

Case	Open Phases	Voltages across open circuits	Line currents across open circuits
A (1)	a	$v_\beta = 0;\ v_\alpha = 2v_o$	$I'_\alpha = -I'_o$
A (2)	b	$v_\alpha = -\frac{v_\beta}{\sqrt{3}} = -v_o$	$I'_\alpha - \sqrt{3}I'_\beta - 2I'_o = 0$
A (3)	c	$v_\alpha = -v_o = -\frac{v_\beta}{\sqrt{3}}$	$I'_\alpha + \sqrt{3}I'_\beta - 2I'_o = 0$
B (1)	b and c	$v_\alpha = -v_o$	$I'_\alpha = 2I'_o;\ I'_\beta = 0$
B (2)	a and b	$v_\alpha + \sqrt{3}v_\beta - 2v_o = 0$	$I'_\alpha = \frac{I'_\beta}{\sqrt{3}} = -I'_o$
B (3)	a and c	$v_\alpha - \sqrt{3}v_\beta - 2v_o = 0$	$I'_\alpha = -I'_o = -\frac{I'_\beta}{\sqrt{3}}$

$\propto$, β, o Networks to Represent Open Circuits:

Considering Case B (1) of Table II, we can draw the network for the condition as in Fig. 15. In a similar manner, all kinds of open circuit conditions can be represented by means of $\propto$, β, o networks.

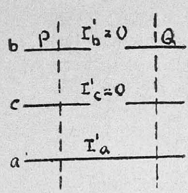


Fig. 15 (a)

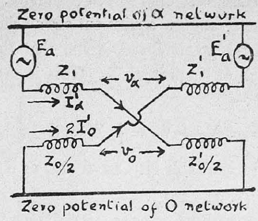


Fig. 15 (b)

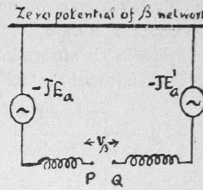


Fig. 15 (c).

Simultaneous Open and Short Circuits:

If the rotating machines connected to a system, can be assumed to have equal positive and negative sequence impedances, all possible kinds of faults can be represented in an A. C. Network Analyser. By using modifications of the β and o networks, simultaneous faults can be represented by direct connections of

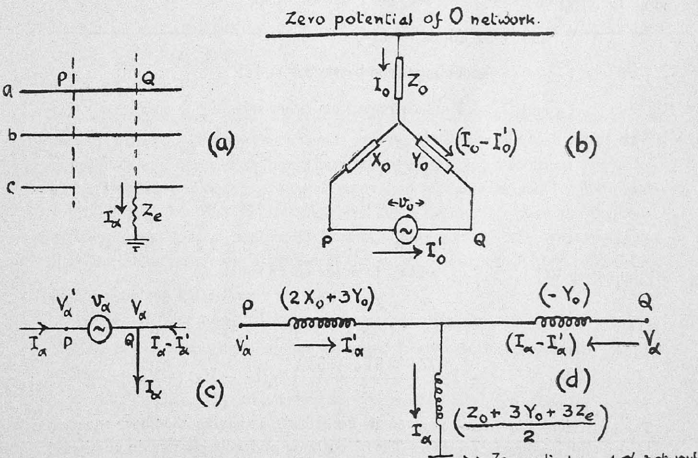


Fig. 16. Open conductor and Fault on Phase 'a'.

the component networks. The case of one open conductor, with a line to ground fault will be considered here, and an equivalent circuit developed. Assume that line 'a' is open between the points P and Q, and that the fault is at Q, where line 'a' is earthed through an impedance Z_e. This is shown in Fig. 16 a. The conditions at the fault are :—

$$I_b = I_c = 0;\ V_a = V_\alpha + V_o = I_a Z_e = (I_\alpha + I_o) Z_e.$$

From these relations, and from Table II, Case A (1), we obtain the following :—

$$I_\beta = 0;\ v_\beta = 0;\ I_\alpha = 2I_o;$$

$$v_\alpha = 2v_o;\ V_\alpha = -V_o + I_\alpha\left(\tfrac{3}{2} Z_e\right) \text{ and } I'_\alpha = -I'_o.$$

The β network is unaffected by the open conductor and fault. In Fig. 16 (b), the O network is replaced by an equivalent star network, (retaining points P and Q and ground), where,

v_o = Voltage drop between P and Q.

V_o = Voltage to ground at Q.

I_o and I'_o = Currents flowing from P and Q.

Fig. 16 (c) gives the α circuit between P and Q, where,

V_α and $'_\alpha$ = Alpha voltages at P and Q.

v_α = Voltage drop between P and Q.

I_α and I'_α = Fault currents from either side.

From these, it can be seen that,

$$V_o = -I_o(Z_o + Y_o) + I'_o(Y_o)$$

$$v_o = V'_o - V_o = I_o Y_o - I'_o(X_o + Y_o) \qquad (81)$$

$$V'_\alpha = V_\alpha + v_\alpha$$

Eliminating V_o, I_o, I'_o, v_o, and v_α from the above equations,

$$V'_\alpha = I_\alpha\left(\frac{Z_o + 3Y_o + 3Z_e}{2}\right) + I'_\alpha(2X_o + 3Y_o) \qquad (82)$$

$$V_\alpha = I_\alpha\left(\frac{Z_o + 3Y_o + 3Z_e}{2}\right) + (I_\alpha - I'_\alpha)(-Y_o)$$

The equivalent star circuit is given in Fig. 16 (d), satisfying the above equation. If the fault is direct, $Z_e = 0$. The β currents and voltages remain unaffected. In the zero network, $v_o = \frac{1}{2}v_\alpha$; $I'_o = -I'_\alpha$; $I_o = \frac{1}{2}I_\alpha$ and $V_o = -V_\alpha + I_\alpha(\frac{3}{2}Z_e)$. With these relations, the zero components in all parts of the system can be determined. The fault condition worked out above can be represented in an A. C. Network analyser as in Fig. 17.

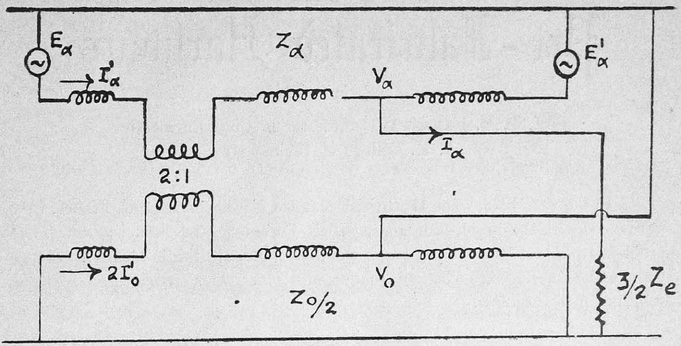


Fig. 17. Modified Network for use with Analyser.

It will be seen that the circuit employes a mutual coupling to satisfy the open circuit, and direct connection for the fault condition.

Conclusion:

It will be seen from the brief survey of the subject given in this article, that the use of α, β and o components, requires far less work, in all cases, where the positive and negative sequence impedances of rotating machines connected to power systems, are equal. Simpler equivalent circuits become possible, since mutual impedances due to unsymmetrical static circuits are zero or reciprocal, unlike in symmetrical component theory. This new system of components, therefore, deserves greater attention at the hands of all Power System Engineers.

Bibliography and References:

The author gratefully acknowledges his indebtedness to the following articles and books, which he has consulted freely in the preparation of this article.

(1) "Short Circuit currents on Grounded Neutral Systems"
by W. W. Lewis, Gen. Elec. Rev., June 1917.

(2) "Problems solved by Modified Symmetrical Components"
by Edith Clarke, Gen. Elec. Rev., November and December, 1938.

(3) "Circuit Analysis of A. C. Power Systems"
by Edith Clarke, Vol. I (John Wiley and Sons)

Pre-Fabricated Harbours

by

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A. H. College of Technology

In the year 1943, when the British planned for the invasion of France, they were faced with the problem of landing their Forces on the French coast. The problem arose because at that time, if you remember, all the harbours in France were under the Germans who had conquered them. This article deals with the solution of the problem.

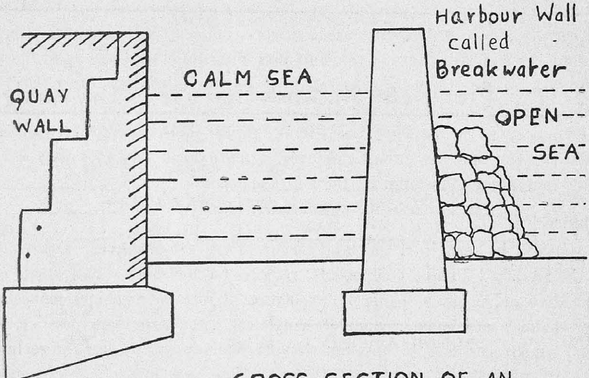
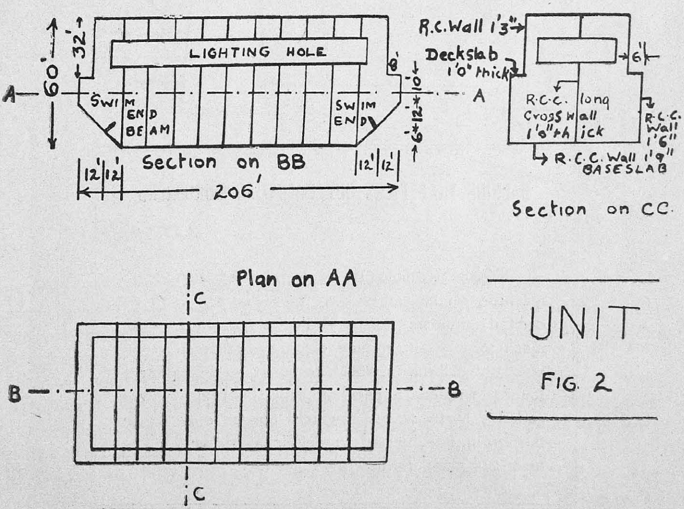


FIG. 1 CROSS-SECTION OF AN ARTIFICIAL HARBOUR

The Fig No. 1 shows a cross section of an artificial harbour. The function of the harbour wall is evident from this drawing. The problem in the case of the pre-fabricated harbours was how to find a means which will serve as a harbour wall, a length of one mile of which can be brought into being overnight. It was solved in the following way: Boats, 204′ x 60′, as shown in the Fig. No. 2, in reinforced concrete, were constructed in the docks of London and Portsmouth. They were towed by steam boats to the French coast and were positioned in a few hours, as shown in the Fig. No. 3. From section A-A of Drawing No. 3, it is clear how the R. C. C. boat served as a harbour wall. These R. C. C. boats were called 'Caissons' or simply 'Units'.

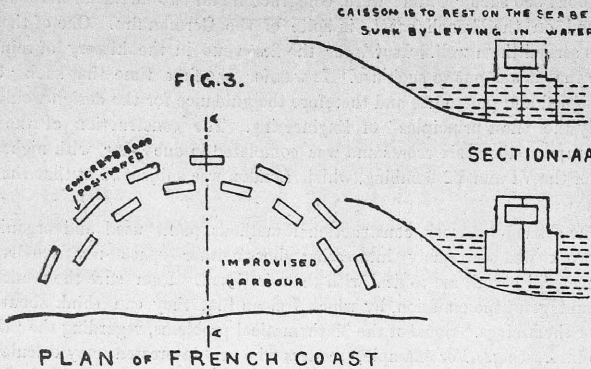
About 300 such 'Units' were constructed and two artificial harbours were established on the French coast, in spite of the German fire. One of these two harbours served them well. It was for the first time in the history of reinforced concrete that it was put to such use. It was for the first time that such 'Units' were designed and put to use and therefore the guidance for the design would have been only the 'first principles' of Engineering. The construction of the boats costs, in rupees, about six crores and was completed in one year, with night work, in spite of the V1 and V2 bombing, which London was subject to at that time.

The setting-out work, constructional methods, plant used and organisation in the work was extremely interesting, but neither space nor the readers' indulgence, will permit me to deal with them in detail. I am sure the readers can take advantage of the omission, by which I mean that they can think about these things for themselves. Some of the Mathematical problems, regarding the 'UNIT' was also interesting. For example, readers who are interested may calculate the position of the centre of gravity and the meta-centre of the 'Unit' the draught of the Unit (that is, the depth of the Unit that will be below water when the unit is floating), and lastly, the weight necessary to be placed in any given position to corrrect the longitudinal or transverse list of the Unit — the list is the angle made by the axis of the boat with the horizontal. Good lord this looks like home-work.



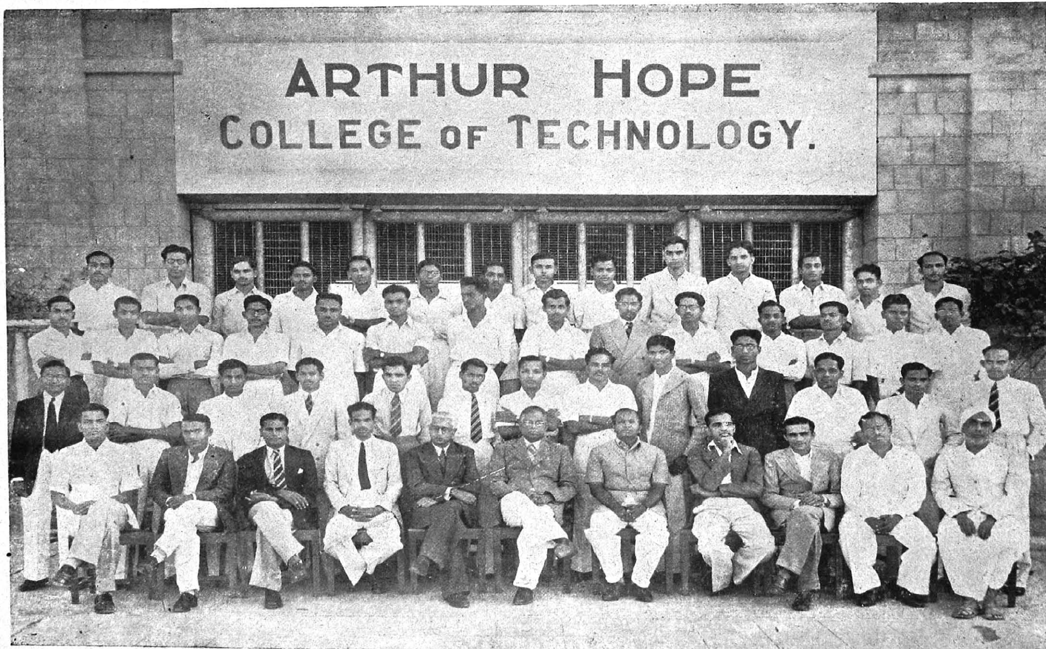
UNIT

FIG. 2



MACHINE THAT PICKS OUT POTENTIAL MURDERERS

British psychologists have invented an electric machine which can pick out men who are liable to commit murders on a slight provocation. The machine picks up minute electric discharges given off by the brain tissue. Impulsive criminals are found to radiate a peculiar type of brain waves called "Theta waves" which appear only when the brain is subjected to emotional stresses. The theory is being further investigated.

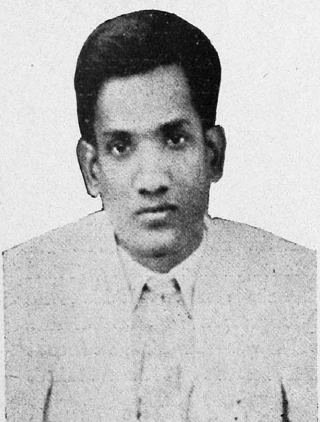


.. Alma Mater first in thoughts

Prof. R. C. Advani,

B. Sc. (Bom.), B. Sc. Tech., A. M. C. T. (Manchester), A. M. I. E. (India), M. M. E. A. (Ind.).

...Our New Professor in Electrical Engineering.



Mr. A. P. Jambulingam, B. E.

Instructor.

...Left on Deputation to America.

Development of Electric Railways

by

Prof. R. C. ADVANI, B. SC., (Bom.) B. SC., Tech. (Manch.) A. M. I. E. (Ind.)
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The term 'railway' was originally used for the road on which the wheels carried the traffic. These roads were constructed with slabs of stones or timber. These were laid in parallel continuous lengths. Over the timber flat iron strips were fixed by means of screws. The lines so constructed were called railway. Later on strips were turned up on either outer or innner edge with a view to increase its durability. Finally modern practice was conceived when in 1788, William Jessop invented flanges on wheels. These flanges not only prevented the truck leaving the track, but helped in switching on to side track from the running track.

The wheels of the vehicle were formally hauled by animal power, mostly horses and mules. The animal power was expensive and depreciation was rapid. The service was slow and it did not supply enough draw-bar pull and speed. When the animal power was replaced by electric power for the street car in America, a wondering Negro exclaimed "First dey freed de darky and now dey freed de mule".

The idea of steam traction occured in the latter half of the eighteenth century with the invention of steam engine. For many years the steam traction was confined to the colliery lines only. The commercial passenger service came in the year 1830. The first locomotive was built in France by Cugnot in 1769, but owing to the break of the French Revolution its progress was retarded in that country. The year 1789 saw a steam locomotive run on the road in England. It was built by Watt. The year 1802 was a stepping year for steam traction when Trevithick built a locomotive with smooth wheels to run on smooth rails for the colliery lines at Merthyr Tydvil in Wales. The wheels were light and provided insufficient adhesion. It brought doubt in the minds of some of the scientists as to its survival. But William Headley showed by experiment that if sufficient weight was concentrated on the driving wheels it would be possible to design a locomotive with smooth wheels which could be worked on smooth rails. The locomotive so designed would develop sufficient effort to haul a train of loaded wagons. In support of his suggestion he actually placed such locomotive on a Wylam Colliery near Newcastle in 1813. He Christened his locomotive "Puffing Billy". The engine worked continuosly for 50 years over 5 miles of the line.

The first commercial railway for carrying passengers and goods by the steam power was constructed in England and opened to the public in 1830.

India was not far behind in her railways. We are told that a proposal was submitted in 1844 to the East India Company and in 1849 a contract was made for constructing two lines. Two companies Viz: The Great Indian Peninsular and The East Indian Railways were formed. On 18—4—1853 the Great Indian Peninsular Railway between Bombay and Thana, a distance of twentyone miles, and the East Indian Railway between Howrah and Hooghly, a distance of twentythree miles on 15—8—1854 Before Partition 55,994 track miles consisting of broad, metre and narrow gauges served an area 15,77,000 square miles.

While the steam traction was being commercialised and its progress maintained at a rapid rate, investigation was going on to apply electric power to traction in America and England. The primary batteries were the source of electric power in those days. The first experimental electric railway which used a small electric motor was introduced in 1835 by a poor blacksmith, Thomas Dowenport, of Brandon, Vermont, U. S. A. He made 100 models of electric railway motor cars all operated by batteries. One patent specified 'The production of rotary motion by repeated changes of magnet poles', and the use of commutator. About three years later a Scotsman named Robert Davidson built another locomotive. Its equipment was two motors coupled to two axles of the wagon. The motors were supplied from iron-zinc sulphuric acid battery. Each axle was provided with wooden cylinder on which were fastened three bars of iron parallel to the axle. Four electro-magnets attracted the bars on each side of each cylinder. Alternately current was cut off and on to produce rotation. 4 miles per hour speed was attained with the locomotive. But due to jealousy it was purposely wrecked by a steam railway engineer who was afraid that it would supersede the types in use at that time. In 1847 Prof. Moses, G. Farmer operated an electric car carrying two passengers at Dover, Newhamshire. The motion was produced by alternate attraction and repulsion of the magnets. It is said that battery supplying the power was utterly damaged. On 29th April 1851, Prof. Page of Smithsonian Institute attained a speed of 19 miles per hour, a record speed, with his car. He obtained the motion from two solenoids which alternately attracted cores on a plunger. The reciprocating motion so obtained was transmitted to the wheels by means of a crank. The supply for the motors was obtained from 100 cells nitric acid battery.

For some years there was no progress but the scientists were engaged in the development of motors and generators. In 1858 an unknown inventor discovered the principle of self-excitation of the generators. A French scietist Gramme introduced this principle in his generators. and later on in motors. A chance discovery brought to light motoring action of the generator. Prof. Farmar introduced the third rail as conductor and Thomas Hall geared speed reduction between the motor and driving axle.

In 1879 at the Berlin Trade Exhibition a German scientist Werner Von Siemens, exhibited the first electric locomotive. It had 3. h. p. motor and with this he attained a speed of four miles per hour in a 600 yards long track with thirty passengers. The power for the motor was supplied from the third rail which was patented in 1840 in England and 1847 in America. A 160 volt dynamo supplied the requisite power. The motor was geared to wheel by spur and bevel gear. The first electric railway opened to public was in 1881 when Siemens and Halske built a line of one and half mile in length to Lichterfielde. The power was transmitted from the motor to driving axles which were provided with steel cables. The car had the passenger capacity of 26 persons and attained the speed of 30 miles per hour.

The electrification of railways commenced in England in 1883 when the first section of Magnus Volk's Brighton was opened. Actually it was a tramway. The car had open sides. In 1890 the first underground railway was introduced on a route between King William Street on the north and Stockwell on the south side of the Thames. It was the first of its kind in the world and it marked an epoch in the development of electric traction. This line not only gave impetus to the application of electricity to the railways, but was the fore-runner of London's underground railways, popularly known as 'Tube Railways'. It also exercised a valuable influence over the development of the electric locomotives. The Tube Railway retarded the progress of the Surface Electrification which tended to lag further behind on account of the ascendancy of the steam traction and the traffic conditions. The steam traction rarely warranted high initial cost which is associated with the electrified lines.

India started the electrification of Railways in the earlies of the present century, nay even earlier in 1895 when Madras opened the first tramway section. Madras was followed by Bombay in 1905. In 1908 Delhi opened its tramway line and was pioneer in the Trolley Bus Service which was started in 1934. The suburban electrification was started by the Great Indian Peninsular Railway from Bombay to Kurla (9⅓ miles) and Reay Road, a few miles outside the city of Bombay on 3rd February 1923. The line was then extended to Thana 23 miles from Bombay and then to Kalyan about 34 miles. The main line electrification from Kalyan to Poona 86 miles and to Igatpuri 52 miles was carried out in 1928 by the Great Indian Peninsular Railway. The Bombay, Baroda and Central India Railway also electrified its suburban line in 1928 for a distance of 22½ miles and then extended further. The South Indian Railway opened metre-gauge line from Madras to Tambaram in 1931.

In early days the electric power supplied to the trains was by 'Third Rail' system or 'Conductor Rail' system. The direct current low voltage was adopted. But when the service extended to long distances requiring high voltages an overhead trolley system was introduced. This system is claimed by J. C. Henery. Whether this be true or not, the word 'trolley' was first coined by an employee as contraction for 'troller' the word first applied to the four-wheeled carriage which was used on overhead wires. The current collector was connected with the car by means of a flexible cable. To keep the trolley on the wire, a boy used to be employed to ride on the top of the car. A trolley pole was later on invented by C. J. Van Depoele, a Belgian mechanic and sculptor. At the end of the pole a grooved pulley was fixed for contact with the wire. Poet Holmes humorously called this pole as 'Witch's broomstick'.

The electrification of railways offers a great number of advantages. They may be divided into three main groups Viz: 1. Direct. 2. Indirect and 3. Power cost. The direct advantages are: (a) Regeneration of power and regenerative breaking which becomes possible if the permanent way is provided with the severe grades. This considerably saves in the wear and tear of brake-shoes associated with mechanical braking. (b) Better facilities are effected at the terminii. These facilities cause saving of time in clearing up the permanent way and of space for the siding accommodation. (c) There is no smoke for the passenger and heat for the driver. (d) Adhesive cœfficient and tractive effort are great.

The indirect advantages are: (a) It offers a great acceleration (1·0 to 2·0 miles per hour per second m.p.h.p.s. with resistance starting and 4·0 m.p.h.p.s. with metadyne starting compared to 0·5 to 1·0 m.p.h.p.s. with the steam. (b) Better facilities at the terminii, higher acceleration and automatic signalling have greatly helped in increase of the track capacity. (c) No firing and steaming up necessary. Hence time saved could be utilised in increasing the service.

Power cost advantages are: (a) Ratio of coal consumed per hour for the steam and electric trains is 2·4: 1 and moreover it permits the use of lower grade of coal in the generation of electric power. Hydro-electric power uses practically no fuel. (b) There is reduced cost of haulage compared with steam traction. (c) Saving in wages cost is considerable. (d) Maintenance cost is much smaller.

Electrification of railways is not free from disadvantages. It requires a large capital cost for generating stations, sub station and transmission lines. The failure of supply may cause disorganisation of the service. It causes interference with telephone and telegraph circuits.

The electric traction has well competed with the steam traction in the case of the suburban service and has established its superiority over it. But when the main line service with its traffic is considered the steam traction gains over it. To have the advantages of the electrification of the railways for the main line 'Diesel Electric Traction' has been developed. The first of its kind was introduced in 1913 as Rail Car of 7. 5. b. h. p. on the Mellersta-Sodermanlands Railways. Its progress was retarded by the Great War of 1914. After the war attention was directed to it. In India Diesel traction was introduced in 1930 by the North Western Railway for the Shuttle Service on the branch lines. In 1933 the Gaekwar's Baroda State Railway ran a Diesel Car on the narrow gauge.

In India, the East as well as in Great Britain, the Diesel traction is still in experimental state, its progress having been impeded by the World war of 1939. America has gone ahead with the Diesel locos for switching services and for high speed trans-continental trains but the European countries in the rail cars.

The superiority of the Diesel electrification is due to its high thermal efficiency, saving in time of starting, clearing fuel, etc., the use of cheap fuel, low running cost and fast service.

A novel single rail traction has been introduced in India to serve the need of countryside as well as a cheap transport. It is known as 'Guideways'. It consists of a four foot cement track with a single rail in the centre to guide the locomotives and bogies along the track. The locomotive is run on Diesel oil and the guideways. It combines the most economical features of both rail and road transport. The guideways can be run on an average speed of 30 miles per hour and has a load capacity of 100 tons.

The experimental stage of the electrification has passed. The electrification of railways has come to stay. The progress will be more rapid in countries as soon as they co-ordinate the hydro and thermal electric power. The power will then be in abundance and cheap. The only impeding factor is the prohibitive high initial cost of the locomotives and track installation.

At the time of going to press, a following piece has appeared in 'The Hindu', November 27th 1948 for trolley buses for Bangalore. Administrative sanction has been accorded by the Mysore Government for the introduction of electric trolley buses in Bangalore city and civil station. The cost of buses along with other equipment like rectifier, sub stations, underground cables, tracks etc. would be Rs. 48,84,000. The annual revenue expected is about Rs. 24·88 lakhs taking into account an average mileage of 200 miles per day per bus, while the total working expenses are estimated to be Rs. 8.89 lakhs. The return on the capital is 33% for a daily performance of 200 miles per bus.

Steady State Stability Criteria in Synchronous Machines

by

VENKATESHA NAYAK SUJEER, B. E.

In this article the three important criteria known as the a, b and c., criteria of the stability of synchronous machines are derived on the basis of per unit quantities. The application of these criteria to the simple case of two machines is considered. An introduction to their application in interconnected systems is given.

List of symbols used :—

E_1 E_2	=	The sending end and receiving end voltages.
H	=	Inertia constant.
I	=	Current.
T	=	Torque.
V	=	Voltage.
Δ	=	Increment.
ω	=	$2\pi f$
ϕ	=	Transmission line impedance angle.
Θ	=	$\text{Tan}^{-1}\dfrac{X}{V}$ = Impedance angle.
P	=	Real Power.
δ_N	=	Angular displacement of vector voltage from reference axis.
δ_{NM}	=	$\delta_N - \delta_M$ = Angular displacement between vector voltages.
$\propto$	=	$90^\circ - \Theta$ = Complement of impedance angle.

The problem of stability of synchronous machines is of very great importance to the power system engineer in modern large interconnected grid systems. A stable generator is one which can carry increased load at reduced voltage without increase of excitation and has the ability to remain in step or synchronism under sudden overloads due to abnormal operating conditions. Power engineers are familiar with the stability limits derived from circle diagrams in synchronous machines. This concept of stability is used for comparing the relative stability of synchronous machines when the system and the type of control devices are not defined. When a system is subjected to faults, shock loadings or even gradual increases in load the stability is a function of all the elements connected to the system. These elements include the control devices such as voltage regulators and governors.

Stability could be classified as (a) Steady state (b) Transient and (c) Hunting (sustained or cumulative oscillation). Steady state stability is the stability of the system under certain conditions of gradual or relatively slow changes in load. The load is assumed to be applied at a rate which is slow when compared either with the natural frequency of oscillation of the major parts of the system or with the rate of change of field flux in the rotating machine in response to the change in loading. Transient stability on the other hand means the stability of the system during sudden changes in load. The phenomenon of hunting occurs when there is a sudden infinitescimal load change.

General Network Equation for Real Power:

The calculation of system performances is simplified by the use of per unit representation of all quantities such as voltages, current, impedance, power or K. V. A. In such a representation a selected base value is considered as unity or 1.0 and the system quantities are expressed as a ratio in decimal form, with respect to the base value of the quantity.

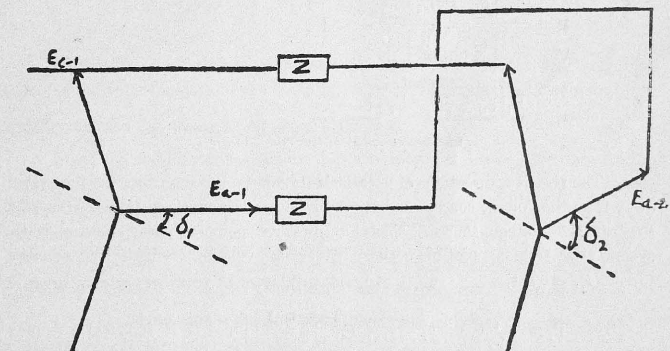


FIG a

The three phase circuit represented in fig. (a) can be replaced for purposes of analysis by an equivalent single phase circuit as shown in fig. (b)

$\overline{E}$, $\overline{I}$ and $\overline{Z}$ are vector quantities.

Θ is the impedance angle of $\overline{Z}$ $\left(\Theta = \tan^{-1}\frac{X}{V}\right)$. Per unit three power then is

$$P_1 = \overline{E}_1 \cdot \overline{I}_1 = E_1 I_1 \cos \beta_1 \qquad (1)$$

$$P_2 = \overline{E}_2 \cdot \overline{I}_2 = E_2 I_2 \cos \beta_2 \qquad (2)$$

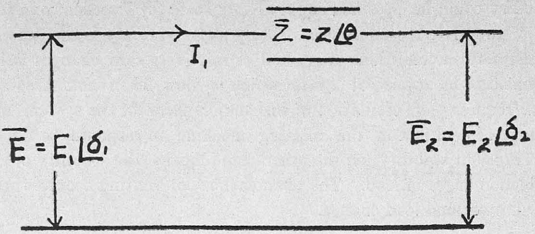


FIG 6

The dot indicates the vector dot product. B_1 and B_2 are the power factor angles at points 1 and 2 respectively.

Further

$$I_1 = \frac{E_1 \angle \delta_1}{Z \angle \Theta} - \frac{E_2 \angle \delta_2}{Z \angle \Theta} = -I_2$$

$$\text{or} \quad I_1 = \frac{E_1}{Z} \angle \delta_1 - \Theta - \frac{E_2}{Z} \angle \delta_2 - \Theta = -I_2 \qquad (3)$$

The positive direction of current is taken as flowing towards the system away from the voltage source and negative current as flowing from the system towards the voltage source. Therefore positive power is power flowing to the system away from a point of positive generated voltage. Substituting equation (3) in (4), we get,

$$P_1 = \frac{E^2_1}{Z} \cos\left[\delta_1 - \delta_1 + \Theta\right] - \frac{E_1 E_2}{Z}\left[\cos(\delta_1 - \delta_2 + \Theta)\right] \qquad (4)$$

$$P_2 = -\frac{E_1 E_2}{Z} \cos\left[\delta_2 - \delta_1 + \Theta\right] + \frac{E^2_2}{Z} \cos\left[\delta_2 - \delta_2 + \Theta\right] \qquad (5)$$

Putting $\delta_1 - \delta_2 = \delta_{12}$, $\delta_2 - \delta_1 = \delta_{21}$ and simplifying, we get,

$$P_1 = \frac{E^2_1}{Z} \cos\Theta - \frac{E_1 E_2}{Z} \cos\left[\delta_{12} + \Theta\right] \qquad (6)$$

$$P_2 = \frac{E^2_2}{Z} \cos\Theta - \frac{E_1 E_2}{Z} \cos\left[\delta_{21} + \Theta\right] \qquad (7)$$

— — — — — — — — — —

$$P_1 = \frac{E^2_1}{Z_{11}} \cos \theta_{11} - \frac{E_1 E_2}{Z_{12}} \cos \left[\delta_{12} + \theta_{12} \right]$$

$$.................. \frac{E_1 E_n}{Z_{1n}} \cos \left[\delta_{1n} + \theta_{1n} \right] \qquad (8)$$

The form of the above equation can be modified to a more suitable form for use in power circuits where the ratio $\frac{V}{X}$, is small; substituting.

$$\theta_1 = 90^\circ - \propto_{11}$$

$$\theta_{12} = 90^\circ - \propto_{12}$$

$$\theta_{1n} = 90^\circ - \propto_{1n}$$

The equation becomes

$$P_1 = \frac{E^2_1}{Z_{11}} S_{1n} \propto_{11} + \frac{E_1 E_2}{Z_{12}} \text{Sin} \left[\delta_{12} - \propto_{12} \right] .... + \frac{E_1 E_n}{Z_{1n}}$$

$$\text{Sin} \left[\delta_{1n} - \propto_{1n} \right] \qquad (9)$$

This is the fundamental general setwork equation for real power, and is the basis for the determination of the stability limits of interconnected machines.

Stability Criteria (a) Based on Dynamic Relations:

Since the stability of a machine depends upon a stable balance between the dynamic forces acting on the rotor, one method of studying it is to solve the differential equations connected with the motion of the rotor. In doing this the following assumptions are made to simplify the calculations.

(i) The synchronous machine or group of machines is represented as an equivalent reactance which gives the steady state or response to load change.

(ii) The equivalent reactance which gives the sustained response is used to represent the synchronous machine for small transient oscillations.

(iii) The mechanical torque inputs are considered constant.

(iv) The change in system speed is neglected and power is taken as equal to torque.

(v) The damping torques are neglected, and

(vi) The changes in displacements are held small. As the rate of change of momentum is equal to the moment of the forces acting on a body the accelerating torque T is given by.

$$T \left[\text{pound feet} \right] = \frac{W R^2 \propto}{32{\cdot}2} \qquad (10)$$

Where $\propto$ is the angular acceleration in radians per second per second. The mechanical angular acceleration is the electrical angular acceleration divided by the number of pairs of poles.

$$\therefore \propto = \frac{2}{P} \cdot \frac{d^2 \delta}{d t^2} \text{ where } \frac{d^2 \delta}{d t^2} = \text{ electrical angular acceleration in elec-}$$

trical radians per second.

$$P = \frac{2 \times 60 \times f}{r\,p\,m} = \text{number of poles.}$$

$$f = \text{normal frequency}$$

$$r\,p\,m = \text{revolutions per minute}$$

$$\propto = \frac{r\,p\,m}{60 \times f} \cdot \frac{d^2 \delta}{d t^2}$$

It is desirable to express the torque of equation (10) in per unit terms by dividing the accelerating torque in pound feet by the unit torque. Unit torque can be defined as the torque required to produce unit K. W. at rated speed or

$$\text{Unit (T)} = \frac{\text{Unit K W}}{1{\cdot}42 \times r\,p\,m \times 10^{-4}} \qquad \text{.....................................(11)}$$

In the per unit system unit K. W. is usually assumed to be equal to unit K. V. A.

$$\therefore \text{Unit T} = \frac{\text{K V A [base]}}{1{\cdot}42 \times r\,p\,m \times 10^{-4}}$$

$$\text{Substituting } \propto = \frac{r\,p\,m}{60\,f} \text{ in equation} \qquad (10)$$

and dividing the accelerating torque T by the unit torque, we get,

$$\frac{T}{T\,[\text{unit}]} = \frac{0{\cdot}231 \times W\,R^2 \times \overline{r\,p\,m}^2 \times 10^{-6}}{\pi f \times \text{K V A [base]}} \cdot \frac{d^2 \delta}{d t^2}$$

which can be put down as

$$\frac{H}{\pi f} \cdot \frac{d^2 \delta}{d t^2} = \text{Taper unit torque with}$$

$$H = \frac{0{\cdot}231 \times W\,R^2 \times \overline{r\,p\,m}^2 \times 10^{-6}}{\text{K V A [base]}}$$

H in the above equation is the per unit inertia constant and has the dimensions of K. W. seconds per K. V. A.

To obtain the steady state stability by this method the differential equations of motion of the various machine groups have to be written in accordance with the assumptions already made, since the damping torque terms can be neglected resulting in an equation involving only powers of the square of the Heaviside differential operator p.

Considering equation (11)

$$P_1 = \frac{E_1^2}{Z_{11}} \operatorname{Sin} \propto_{11} + \frac{E_1 E_2}{Z_{12}} \operatorname{Sin} \left[\delta_{12} - \propto_{12} \right] \cdots\cdots\cdots + \frac{E_1 E_n}{Z_{1n}}$$

$$\operatorname{Sin} \left[\delta_{1n} - \propto_{1n} \right]$$

$$\triangle P_1 = \frac{E_1 E_2}{Z_{12}} \cos \left[\delta_{12} - \propto_{12} \right] \triangle_{12} \cdot \delta_{-12-} \cdots\cdots\cdots + \frac{E_1 E_n}{Z_{1n}}$$

$$\cos \left[\delta_{1n} - \propto_{1n} \right] \triangle_{1n}\, \delta_{1n}$$

or $\triangle P_1 = K_{12} \triangle \delta_{12}$ — — — — — $K_{1n} \triangle \delta_{1n}$

Where $K_{JK} = \dfrac{E_J E_K}{Z_{JK}} . \cos \left[\delta_{JK} - \propto_{JK} \right]$

The equation of motion of a generator neglecting the effect of damping is

$$\frac{H_1}{\pi f} \cdot \frac{d^2 \delta_1}{d f^2} = T\propto = T_{m_1} - T_{e_1}$$

Where H = Inertia constant

$$= \frac{0{\cdot}231 \times W R^2 \times \overline{r p m}^2 \times 10^{-6}}{K V A \ [\text{base}]}$$

δ_1 is the angular displacement of machine measured in electrical radians with respect to a reference axis rotating at such speed.

T_{m_1} = mechanical torque of machine 1

T_{e_1} = electrical torque of machine

t = time in seconds.

For small changes, assuming constant mechanical torque and putting power = torque, we have,

$$\frac{H_1}{\pi f} \cdot \frac{d^2 | \triangle \delta_1 |}{d t^2} = - K_{12} \triangle \delta_{12} - K_{13} \triangle \delta_{13} \ldots\ldots\ldots - K_{1n} \triangle \delta_{1n}$$

For a group of synchronous machines

$$\frac{H_1}{\pi f} p^2 \triangle \delta_1 = - K_{12} \triangle \delta_{12} - K_{13} \triangle \delta_{13} \ldots - K_{1n} \triangle \delta_{1n}$$

$$\frac{H_2}{\pi f} p^2 \triangle \delta_2 = - K_{21} \triangle \delta_{21} - K_{23} \triangle \delta_{23} \ldots - K_{2n} \triangle \delta_{nn}$$

$$\ldots\ldots\ldots \triangle \delta_{12} = \triangle \delta_1 - \triangle \delta_2$$

The criterion for stability is that all roots for p^2 are real and negative since thereby all values of p will be imaginary. If however any of the roots of p^2 are real and possitive values of p which are real and positive will exist. This indicates that displacements will increase indefinitely with time or that instability exists. Whether or not any real and positive roots of p^2 exist can always be determined. The simple case of two machines will be used to illustrate the application of this method of testing for stability.

$$D = \begin{vmatrix} - K_{12} - \dfrac{H_1 p^2}{\pi f} & K_{12} \\ K_{21} - K_{21} & \dfrac{-H_2 p^2}{\pi f} \end{vmatrix}$$

$$\text{or } D = \frac{K_{21} H_1 p^2}{\pi f} + \frac{K_{12} H_2 p^2}{\pi f} + \frac{H_1 H_2}{\pi^2 f^2} \cdot p^4$$

In this case stability exists if $K_{21} H_1 + K_{12} H_2 > O$

For the case of no — resistance in the network between machines 1 and 2. $\propto_{12} = \propto_{21} = O$.

$\therefore K_{21} = K_{12}$ and stability exists for all values of δ_{12} from $-\frac{\pi}{2}$ through Zero to $+\frac{\pi}{2}$ and instability occurs for all values of δ_{12} from $\frac{\pi}{2}$ through π to $-\frac{\pi}{2}$

If for the case of resistance in the circuit between machines 1 and 2_2 $\propto_{12} = \propto_{21} = \tan^{-1} \frac{r_{12}}{K_{12}}$

$H_1 \cos [\delta_{21} - \propto_{12}] + H_2 \cos [\delta_{12} - \propto_{12}] > 0$ or $\cos \delta_{12} . \cos \propto_{12}$, $[H_1 + H_2] - [H_1 - H_2] \text{Sin } \delta_{12} . \text{Sin } \propto_{12} > 0$

The critical angular displacement is $\delta_{12} = \tan^{-1}$

$$\left[\left(\frac{H_1 + H_2}{H_1 - H_2}\right) \frac{K_{12}}{r_{12}} \right] \qquad (12)$$

For the case of series resistance between machines 1 and 2, $\frac{K_{12}}{r_{12}}$ is positive, whereas for the case of a shunt resistance load between machines 1 and 2 with a small series line resistance, $\frac{K_{12}}{r_{12}}$ is positive

The criterion expressed by the equation (12) indicates that if $H_1 = H_2$ and $\frac{K_{12}}{r_{12}} > 0$ stability may be obtained from $\delta_{12} = -\frac{\pi}{2}$ through zero to $\frac{\pi}{2}$ as in case of $r = 0$.

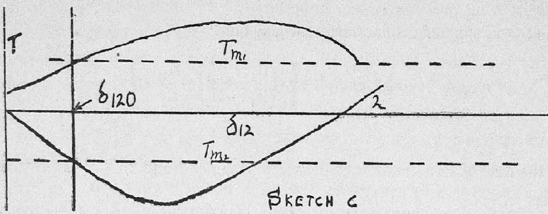
If H_2 is large compared to H_1 and $\frac{K_{12}}{r_{12}} > 0$ stability is obtained from $\delta_{12} = \left[-\frac{\pi}{2} + \propto_{12} \right]$ through Zero to $\left[\frac{\pi}{2} + \propto_{12} \right]$ or up to the peak output and input of machine one.

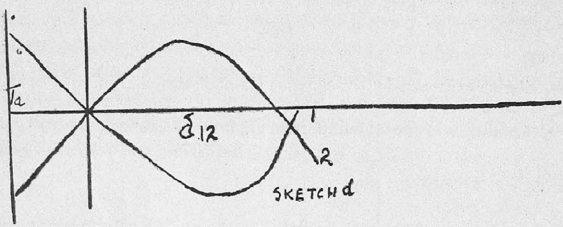
If H_1 is large compared to H_2 and $\frac{K_{12}}{r_{12}} > 0$ stability is obtained from $\delta_{12} = \left[-\frac{\pi}{2} - \propto_{12} \right]$ through 0 to $\left[\frac{\pi}{2} - \propto_{12} \right]$ corresponding to peak power output and input of machine two.

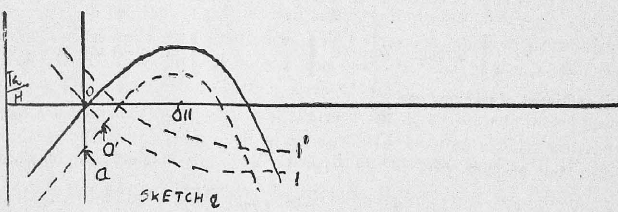
If the network contains a predominant shunt resistance effect corresponding to $\frac{K_{12}}{r_{12}} < 0$ stability is obtained for large values of H_2 compared to H_1 from $\left[-\frac{\pi}{2} - \propto_{12} \right]$ through zero to $\left[\frac{\pi}{2} - \propto_{12} \right]$ whereas for large values of H_1 compared to H_2, from $\left[-\frac{\pi}{2} + \propto_{12} \right]$ through zero to $\left[\frac{\pi}{2} + \propto_{12} \right]$

Stability Criterion.

[Based on angular displacements and inertia effects of machines]







Consider two synchronous machines a generator and a motor connected together by means of a line having a series resistance and operating at an initial angular displacement δ_{120}. Sketch (d) is a plot of the generator and motor accelerating torque which is equal to the difference between mechanical shaft torque input and the electrical torque output,

Figur (e) is a plot of the accelerating torques of (d) divided by their respective inertia constants H_1 and H_2, operation from the initial point of equilibrium can be analysed as follows:— If an increase or decrease in angular displacement δ_{12} is given to the system without a change in the load, the accelerating and decelerating torques will act to return the system to the point of stable equilibrium. If a small additional load is placed on the motor corresponding to the dotted line the motor tries to decelerate. There is a decelerating torque acting on the motor and a certain time elapses before it catches up with the generator at some point such as O′. The system frequency is now less and the prime mover tries to supply more power to bring back the system to normal. A new point of equilibrium O″ is now reached. At this point of equilibrium machine two is carrying an additional load and the system is operating at normal frequency. Since the system was capable of remaining in synchronism and at normal frequency after the load change, it can be considered to be stable for the initial loading corresponding to δ_{120}. It can be shown by a similar reasoning that when the motor and generator are operating with an angular displacement of 90°, the governor of machine one acts to restore the speed by increasing the prime mover torque and this tends to increase δ_{12} still further. Therefore for this case both methods of testing for stability would find the system unstable for this particular operating conditions. If the effect of inertia is also taken into account as is necessary when the motor inertia is large compared with the generator inertia a momentary forcible increase in angular displacement δ_{12} will result in the generator slowing down more rapidly than the motor, thus returning the system to its original operating angle or position. This method of testing for stability indicates a stable operating point, even though the motor is operating at a point corresponding to a positive slope in its power angle characteristic.

Similarly it can be shown that for series resistance and with a large motor inertia compared with the generator inertia the system in this region of questionable stability can operate with a momentary increase in angular displacement but cannot be stable for a sustained increase in motor load. The first fact is of theoritical interest, while the latter is of practical importance. In a similar manner the two cases when the generator and motor are connected to a shunt resistance could be analysed. The stability for the simple case of two machines when the machine two is subjected to a sustained small load increase, is $-\frac{\delta P_2}{d\,\delta_{12}} \cdot \frac{1}{H_2} > -\frac{d P_1}{d\,\delta_{12}} \cdot \frac{1}{H_1}$. When more than two machines are involved, it becomes increasingly difficult to determine the exact stability limit, for sustained increase in load in the region, where one of the units has a negative synchronising power coefficient. The answer depends not only on the relative inertia of the machines but on their rates of governor response as well.

Stability Criterion (C)

This criterion for study state stability depends on an increase or decrease in power occuring with an increase in angular displacemet, with change in angle ($d\,\delta_1$), field currents of all machines of the system remaining constant and the governor sittings being adjusted to maintain system frequency. Since it is difficult to predict the manner in which load will be distributed between the generators of a system due to small incremental load change, the distribution of load has to be assumed. A conservative steady state limit is obtained if it is assumed that an increment of shaft load is taken by one machine only with the added generation being taken by one other machine and with all the other machines operating at constant power. If this is done in turn for all the machines of the system, and if in all cases the synchronising power coefficient is positive for both the machines required to pick up the shaft load and the generator assigned to pick up the resulting generation, the system is said to be stable at the assumed operating condition. If either one of the machines has a negative synchronising coefficient the system is unstable by this criterion. In applying the method, the machine on which the shaft load is increased and the machine assigned to pick up the corresponding generation are usually the two machines having the largest relative angular displacement, since, these are the two which would be the least stable. All remaining machines are treated as constant power machines with no change in their generation or shaft power. The machine with the smallest angular displacement is treated as an equivalent motor and the machine with the largest angular displacement is treated as a generator for the test increment in load.

The procedure to be followed in calculating the steady state stability by this conservative method is:

(1) Reduce the system to its simplest form preserving the identity of points at which specified voltages or power factors are maintained.

(2) Under given operating conditions calculate the internal voltages of all machines in magnitude and phase for an assumed load.

(3) Calculate the transfer impedences between all machines.

(4) Calculate the $\frac{dP}{d\delta}$ of the machines in accordance with the assumed load distribution.

(5) If the system is stable for the assumed load increase the load and proceed as before until steady state limit is reached. For each additional assumed initial load, the voltages corresponding to the field excitation of the synchronous machines are changed to maintain the specified system voltages.

In many cases the problem is simplified by the use of a network analyser. In using this the following procedure has to be adopted:

(1) Determine the initial voltage and power angles of the equivalent synchronous machine groups.

(2) With constant voltage held back of the equivalent synchronous reactances of the machine groups increasing the angular displacements between two of the machine groups.

(3) Adjust the angular displacement of the remaining machine groups so that their power output remains unchanged.

(4) Determine whether the power input to the lagging machine test machines and the power output of the leading test machines have both increased i.e., whether $\frac{dP}{d\delta}$ of both machines is positive. In making this test it may be advisable to decrease the angular displacement between the two machines selected for the test, to determine more exactly the shape of the power angle curve. This allows for a large power increment to be applied for the test.

(5) If the $\frac{dP}{d\delta}$ of each machine is positive the system is stable. Increase the system loading in accordance with assumed load increase and proceed as before until stability limit is reached.

Simple Case of Two Machines.

For two machines, the equation of power is

$$P_1 = \frac{E_1^2}{Z_{11}} \operatorname{Sin} \propto_{11} + \frac{E_1 E_2}{Z_{12}} \operatorname{Sin} \left[\delta_{12} - \propto_{12} \right]$$

$$P_2 = \frac{E_2^2}{Z_{22}} \operatorname{Sin} \propto_{22} + \frac{E_1 E_2}{Z_{12}} \operatorname{Sin} \left[\delta_{21} - \propto_{21} \right]$$

Differentiating with respect δ_{12} and δ_{21}, respectively.

$$\frac{d P_1}{d \delta_{12}} = K_{12} ; \frac{d P_2}{d \delta_{21}} = K_{21}$$

Discussion of the Criteria.

Criterion (a) based on dynamic relations neglecting governor action is in general optimistic, indicating in some cases stability when stability may not exist. On the other hand the criterion which requires only that the synchronising power coefficient $\frac{d P_m}{d \delta_{mn}}$ be positive, neglecting inertia effects is pessimistic, indicating instability when the system is stable. The more correct criterion (b) including both interia and governor action is difficult of application for more than two synchronous machine groups. To summarize these three criteria, criterion c is the most easily applied. Since it is also conservative, it will in most cases, be preferable. Most systems are operated with substantial steady state margins. If the margin is found to be small or non-existant by the conservative criterion c, further study may be made to determine more accurately the actual limit, going through an analysis of the type described under criterion (b). For long lines having a predominent series resistance effect, which are usually the most frequent steady state stability cases, criterion c, yields theoretically correct results.

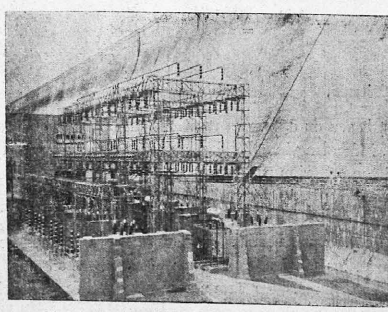
References.

(i) Power system stability — Steady system stability by Selden B. Crary.

(ii) System stability as a design problem by R. H. Park and E. H. Barcker.

(iii) Power limits of synchronous machines by Mrs. Edith Clarke and R. Y. Lorraine.

(iv) Steady state stability of composite systems by S. B. Crary.



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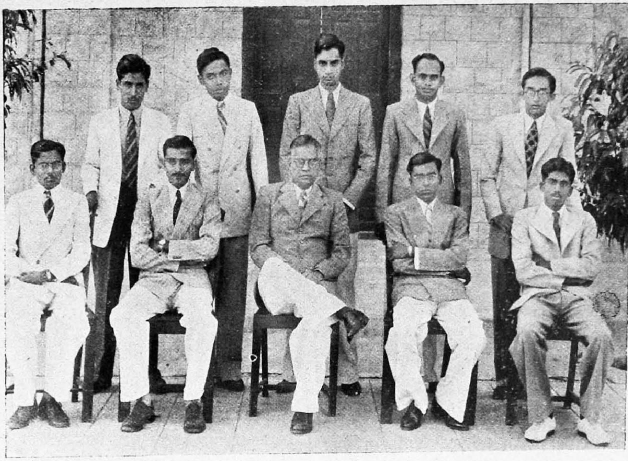

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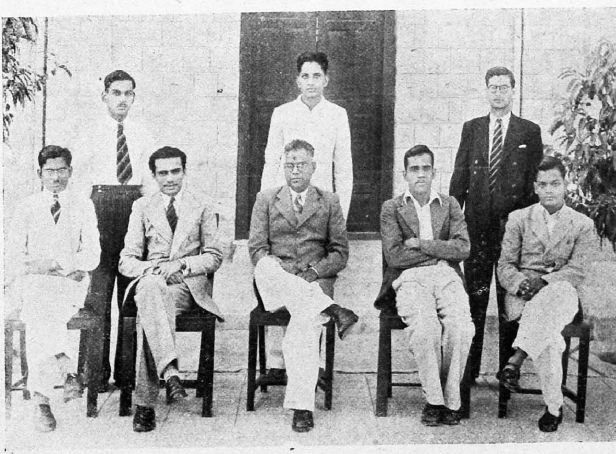

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Earth Pressure - A New Theory

by

Ch. RAMA RAO, B. SC., IV B. E. (Civil)

Summary :— In this article a new theory of lateral earth pressure on a retaining wall is proposed, which takes into account dilatancy of soil particles, their friction, cohesion, consolidation, permeability etc.,

Soil mechanics, though not quite the name for the subject with which it is dealing, yet considering it as a branch of Civil Engineering, is the application of laws of mechanics and hydraulics to engineering problems dealing with earth and mantle, which are sediments and other unconsolidated accumulations of soil particles produced by the mechanical and chemical disintegration of rocks, regardless of whether or not they contain an admixture of organic constituents.

There have been many theories concerning the lateral pressure exerted by earth retained by a wall, of which Prof. W. M. Rankine's theory of earth pressure, taking into account conjugate stresses on inclined planes, is the simplest one, used for the practical propositions.

The subject of soil mechanics has become a complex one, since soil possesses special properties such as cohesion, dilatancy, arching, friction etc. The property of cohesion may be defined as the bond between the soil particles, and is the shearing resistance of soils at zero pressure. The phenomenon of arching and the experiment to demonstrate it was ascribed by P. M. Crosthwaite to C. J. Meem· No existing theory takes it into account.

Frictional effects are always present in a mass of earth ; those of cohesion may in extreme cases either be negligible or be the predominating factor. So no definite angle of repose can be assigned to a soil with cohesion, because the steepest slope at which such a soil can stand decreases with increasing height of slope and it depends on the condition other than the nature and the initial state of the soil. (Terzhagi.)

Theories of Lateral Earth Pressure.

Rankine's theory of earth pressure :—

Intensity of pressure $= p = wh \dfrac{1 - \sin \phi}{1 + \sin \phi}$ for cohesion less soils.

He supposed the mass of earth under consideration to be unlimited in extent and free from cohesion, dilatancy and arching are neglected and pressures are assumed to increase linearly with the depth of material as in a fluid. In spite of the limitations imposed by these assumptions, the results obtained have been extensively used, for the design of retaining walls. In the case of surcharged walls, he assumes the pressure as acting parallel to the surface of earth. This is found to be adequate in the case of positive surcharges, but gives quite untenable results in the case of negative surcharges. Although this theory offers simple solutions to various problems, designs according to this give uneconomical results and is pointed out by Sir Benjamin Baker in 1881.

Wedge theory of earth pressure was propounded, in which it is supposed that a certain wedge of material behind the retaining wall is on the point of breaking off, and is prevented by the retaining wall. This is semi-empirical and the drawback of this theory being that the three forces, keeping the wedge in equilibrium do not meet at a point.

Coulomb evolved an empirical equation giving the relation between normal stress and shearing resistance.

$$s = c + r \tan \phi$$

s — shearing resistance per unit area.

r — compressive stress,

c — cohesion.

ϕ — Angle of internal friction.

As a result of experimental work, Prof. Jenkin has advanced a new form of wedge theory, which takes into account the phenomenon arising out of dilatancy of granular material.

It is supposed that the resultant pressure is always inclined at Z° (frictional angle between masonry and earth) to the normal to the back of the retaining wall.

Graphical procedures to get the resultant pressure have been given by Rebhann (1871), Culmann (1866), Poncelet (1840), Engesser (1880).

Bell produced a formula in which both cohesion and internal friction were taken into account, but the results of pressures on retaining walls given by this formula are found to be too low, since he assumes the slip surface to be an inclined plane, instead of a circular cylindrical surface; which is pointed out by Fellenius.

Dr. Karl Terzhagi has treated the subject of soil mechanics in detail and brought to light the importance of its study. He showed that compressibility and permeability were the determining factors with regard to settlement and that these might be very different in two soils with identical properties of colloids and with the same grain size. Dr. Terzhagi, in his general wedge theory, uses a logarithmic spiral for the slip surface. An abstract of this method is given in Krinine's work on stability of slopes.

There is a great discrepancy between the results used in practice and the results obtained theoretically, which is mainly due to the fact that the practising engineer might not have the time and patience to go through the latest research, while the theoretical engineer, engaged in a designs office, will be going on framing mathematical equations and finally will lead the problem into a complicated state, which may not be understood by the practising engineer.

It is desirable to have equations and formulæ of simple nature so that the theory and practice may not be separated much from each other.

Basis of the proposed theory: (Phenomenon of dilatancy pointed out by Jenkin). In 1885, Prof. Osborne Reynolds observed this phenomenon and said, "As regards any results which may be expected to follow from the recognition of this property of dilatancy, in a practical point of view it will place the theory of earth pressure on a true foundation."

Jenkin explains the principle of dilatancy as follows:— "The pressure in a granular mass depends on its weight, geometry of boundaries and the geometry of the points of contact between grains and on the co-efficient of friction of the points of contact: Changes in the geometry is the fundamental fact of dilatancy the most striking fact being an increase in volume."

To demonstrate this, Jenkin made two dimensional models in which circular plates took the place of spherical grains and found that the forces exerted considerably varied with the mode of arrangement. His paper contains an exhaustive discussion of it;

Development: In practice, we deal chiefly with soils whose voids are filled with water. If the voids of every soil are completely or partly filled with water, either in a state of flow or in a state of rest, we are obliged to combine the mechanics of solids with applied hydraulics.

Now consider a retaining wall supporting backfill of earth fully charged with moisture. On a microscopical examination, the following facts are revealed.

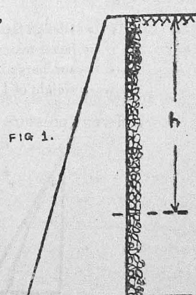
There are interspaces between grains of earth, which are filled with water and are interconnected.

Part of the retaining wall is acted on by water pressure and part of it, by earth pressure.

The grains of earth are pressing over one another; at some places they are closely packed (surfaces are touching) and at other places they are touching one another at their corners only.

The pressure exerted is dependant on many factors such as arrangement of particles, consolidation, density, permeability, compressibility, which may be grouped under cohesion, and also on surcharge and internal friction.

FIG 1.



Derivation of an expression for pressure:

Consider unit area at a depth 'h' from top of retaining wall.

Let it be made up of two areas da and db.

da being the nett surface of the unit area over which water pressure is acting (shown black in fig 2.)

db being the nett surface over which earth pressure is acting.

$da + db = 1$

Lateral pressure exerted $= wh\ da + w_1\ h\ db\ \frac{(1 - \text{Sin}\ \phi)}{(1 + \text{Sin}\ \phi)}\ \frac{w}{w}$

FIG 2.

Let $K = \frac{w_1}{w}\ \frac{(1 - \text{Sin}\,\phi)}{(1 + \text{Sin}\,\phi)}$

For convenience add and subtract a quantity $wh\ db \left(1 - \frac{f}{db}\right)$; w_1 = wt. of 1 c. ft. of earth.

$$p = wh\ da + wh\ db\ k + wh\ db \left(1 - \frac{f}{db}\right) - wh\ db \left(1 - \frac{f}{db}\right)$$

$$= wh\ (da + db) - wh\ f + wh\ db \left[K - 1 + \frac{f}{db}\right]$$

$$= wh\ (1 - f) + wh\ db \left[K - 1 + \frac{f}{db}\right]$$

$wh\ db \left[K - 1 + \frac{f}{db}\right]$; This linean function of h is expressed as the difference of a square and a semi-cube. (Say) $- ch^2 + sh^{3/2}$.

Pressure exerted on unit area at depth 'h' } $p = wh\ (1 - f) - ch^2 + sh^{3/2}$

- f = friction factor
- c = factor taking into account, cohesion compressibility, permeability etc.
- s = surcharge factor.
- w = weight of 1 c. ft. of water.

Different pressure diagrams are shown in fig. 3.

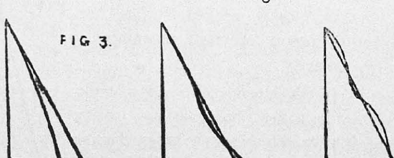


FIG 3.

Our question simplifies to determining the constants f, c, s., So for a particular soil having a certain moisture content, if by some means, the factors c, f, s, are determined, then the question is solved. Total pressure exerted for a

$$\text{height 'H'} = \int_0^H [wh(1-f) - ch^2 + sh^{3/2}]\, dh$$

$$= \Big[w(1-f)\frac{h^2}{2} - \frac{ch^3}{3} + \tfrac{2}{5} sh^{5/2} \Big]_0^H$$

The factors f, c, s, tend to reduce the pressure exerted on the wall. For water, these factors are zero and we get P = wh, a well known equation.

The moisture content in the soil has a great influence over the value of c. Up to a certain percentage of moisture, cohesion increases with the increase in moisture content, beyond that the cohesion again decreases since the earth becomes slurry. (See Fig. 4)

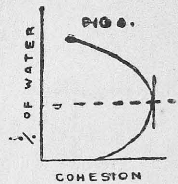


FIG. 4.

This method of approaching the problem of earth pressure may be simple in the respect that we need not burden our memory with a number of assumptions and limitations to the application of formulæ.

This equation may be called Universal Equation, since this may be applied to any fluid, semi-solids, granular or cohesive soils.

There was a controversy between theory and practice regarding the position where resultant acts on the retaining wall.

Authorities on soil mechanics have assumed rather than calculated, that the resultant acts at one-third the height. But in practice resultant is found to lie between 0·33 and 0·55 of the height.

By this theory the position of the resultant need not be assumed but it acts at the height of the C. G. of the pressure diagram.

Distance of C. G. from top of retaining wall:

$$= \frac{\int_0^H [wh(1-f) - ch^2 + sh^{3/2}]\, h\, dh}{\int_0^H [wh(1-f) - ch^2 + sh^{3/2}]\, dh}$$

It has been accepted that the resultant always acts at an inclination of angle of friction to the normal to the back of the retaining wall, and here also it is taken likewise, independent of surcharge, since it is, found to be correct.

This Universal Equation is true both for positive and negative surcharges. In the case of negative surcharge, 's' becomes negative and reduces the pressure.

To illustrate this theory a simple problem may be worked. The soil under consideration is cohesive soil having the following particulars.

Angle of repose of soil — 30°
Value of c — 0·7.
Value of f — 0·6.

For simplicity let there be no surcharge,

Height of retaining wall = 10′
Weight of water = 62·5 lbs. / c.ft.

$$p = w\,(1-f)\,h - ch^{\frac{3}{2}} \qquad s = 0$$

Pressure at depth $10' = 62{\cdot}5\,(1-0{\cdot}6)\ 10 - {\cdot}7 \times 10^2 = 180$ lbs/□′

$5' = 62{\cdot}5\,(1-0{\cdot}6)\ 0 - {\cdot}7 \times 5 = 107{\cdot}5$ lbs/□′

Total pressure
$$P = \Big[W\,(1-f)\,\frac{h^2}{2} - \frac{ch^3}{3} \Big]_0^{10}$$

$$= \Big[62{\cdot}5\,(1-{\cdot}6)\,\frac{10^2}{2} - 0{\cdot}7 \times \frac{10^3}{3} \Big]_0^{10}$$

$$= 1017 \text{ lbs.}$$

Distance of C. G. from top Surface
$$= \frac{\Big[W\,(1-f)\,\frac{h^3}{3} - \frac{c\,h^4}{4} \Big]_0^{10}}{\Big[W\,(1-f)\,\frac{h^2}{2} - \frac{ch^3}{3} \Big]_0^{10}} = 6{\cdot}47'$$

i. e., the lateral pressure is 1017 lbs. acting at 3·53′ above bottom and is inclined at Z° (angle of internal friction) to the back of the wall.

Using Rankine's Theory,
$$P = \frac{w_1\,h^2}{2}\,\frac{(1-\operatorname{Sin}\phi)}{(1+\operatorname{Sin}\phi)} = \frac{100 \times 10^2}{2}$$

$$= \frac{1-\operatorname{Sin} 30^\circ}{1+\operatorname{Sin} 30^\circ} = 1666 \text{ lbs.}$$

neglecting cohesion the lateral pressure is 1666 lbs. acting at 10/3′ above bottom.

A comparison is shown in fig. 5.

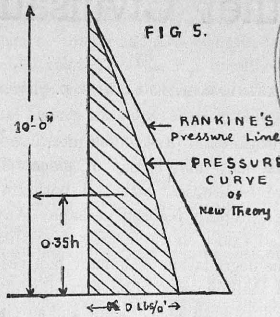


FIG 5.

The property of cohesion may be taken advantage of. Projections are made in the retaining wall as shown at P. & M; which reduce the pressure exerted, which is most probably due to the fact, that certain imaginary wedges of earth are formed, and part of the pressure exerted is used over the surfaces in slight slipping of one surface over the other during the formation itself. The section of concrete shown in fig. 6 is preferable since the resultant is always normal to the bottom curve of concrete.

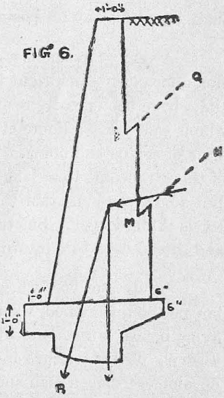


FIG. 6.

Temporary apparatus are being designed to carry out the experiments to determine c, f, s, for any particular soil and and if the results are found satisfactory, the experiments and the tabulated results will be published in due course.

Whither Civilisation?

by

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To write on civilisation and its vicissitudes, in an Engineering magazine (expected to be a technical one), may be out of place. But on second thought, you my readers, will sure realise that after all both are interdependent to an extent which has not been properly realised perhaps. Anyhow, here it is. In the following I have attempted a note on the history of civilisation, if I may say so or perchance a lament on the degradation of human motives and ideals as you will soon see. My purpose, I shall consider to be served, if after perusing this lament, you feel that you have a duty both as engineers and as citizens — a duty which it will indeed be an honour te perform, a glory if performed to success, a duty which shall pave the way for posterity to just cross over, if not to rest on.

A very grievous mistake is being constantly made by attributing to civilisation a meaning which right thinking men will concur is wrong. Especially we in India have been greatly responsible for this. We take a civilised man to be one who is well dressed (more civilised if he is in western robes) and who has a decent style of saying and doing. May be this fault is due to a lack of inner cleanliness of thought or due to a long subjugation by westerners, more correctly Europeans. But admit you must that the fault is there. So, before delay brings detriment, let us think deeper. But that is the present while I want to start from the past and thread it on to a future thro' the present.

In days of yore when country did not know country, when man could speak but not be understood, when distance was a dominant factor in the movements of living beings, where and what was civilisation? Was it rough just because there were no decent clothes and served food? Was there not a moral attachment developed between man and man? Then why call it a barbarous civilisation and call the present one — the decrepit built over the ruins of this past stable structure — modern civilisation existing for the benefit and concord of humanity?

India has contributed a great lot, in fact, to that civilisation which pevailed for such a long time (more than two thousand years) until interrupted and corrupted by people from other places with no capacity to tolerate other ways than theirs. A re-search into our distant past will reveal the enormity of this contribution — a contribution to a worthy cause by a worthy people. It was only because of this generous outlook and broad vision of our ancestors that the then civilisation spread from India outwards as far distant as Persia and Java. This spread was one in my conception, that is yet to find a parallel in history. The efficacy of this statement can best be realised by the following passage from Sylvain Levi. "From Persia to the Chinese Sea, from the icy regions of Siberia to the islands of Java and Borneo, from Oceania to Socotra, India has propogated her beliefs, her tales and her civilisation. She has left indelible imprints on one-fourth of the human race in the course of a long succession of centuries. She has the right to reclaim in universal history the rank that ignorance has refused her for a long time and to hold her place amongst the great nations summarising and symbolising the spirit of humanity."

That was the India of olden days. What a difference between that golden glorious past and this the present. How this change has come to occur is just a lament — a very melancholy lament. From a very bright and powerful, understanding accommodating civilisation that spread because it had a vivid life and attraction about it, we have come down to the present Indian civilisation — a crude mixture of part west and part east, part past and past present ridden with severe obstacles of caste, hatred, jealousy, unnecessary and avoidable differences and a host of such unpleasant qualities.

To us the citizens of the present is left the liberty or destiny to determine and shape our own civilisation. Are we going back to the past — the golden past as I call it? Or Are we turn to new paths not based on our tradition nor based on our outlook? Or Are we to follow the material lead given us by surrounding civilisations? To choose is difficult, and to choose a honourable path is more so. The glory or the blame for the choice shall fall on us the first citizens of a renovated Free India. Let us act — think and act.

Let me close in the words of Tagore. "To know my country, one has to travel to that age, when she realised her soul and thus transcended her physical boundaries, when she revealed her being in a radiant magnanimity which illumined the eastern horizon, making her recognised as their own by those in alien shores who were awakened into a surprise of life; and not now when she has withdrawn herself into a narrow barrier of obscurity, into a miserly pride of exclusiveness, into a poverty of mind that dumbly revolves around itself, in an unmeaning repetition of a past that has lost its light and has no message for the pilgrims of the future." Let this passage be our reminder and our guide.

Let us choose and choose glory for ourselves and for our country.

PRESTRESSED CONCRETE

by

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Idea of Prestressing:

There is nothing new under the sun. Prestressing is no novel device. Now, what is prestressing? As the world itself indicates, it is the process of initially imparting stresses in a material before it is loaded. The principle is so fundamental and logical that the process of prestressing is of pre-historic origin, and its applications existed a ten thousands years ago. A cord tied with an initial tension between the ends of a stave to form a bow — an oldest contrivance for attack — is an example of perhaps the oldest application of prestressing. A wrestler or hoxer tightening up or stressing his muscles before he acts, to make them more fit against external forces, is prestressing. Placing a heated steel hoop around a cart-wheel is again prestressing.

Application of Prestressing to Reinforced Concrete:

The principle of prestressing is so simple and its use so common that it is a great misfortune that its applications to reinforced concrete has not been considered until very recently. Considering the characteristic features of concrete, of all structural materials concrete has most promising latent capacities if prestressed.

Concrete has a very poor tensile strength and under a small tensile force it developes cracks. Hence in a reinforced concrete member the concrete which is bonded to the steel is incapable of adjusting itself to the deformations of the reinforcements. Due to shrinkage of concrete occurrence of hair cracks are more or less unavoidable in reinforced concrete members. These cracks may develop if the tensile stresses exceed certain permissible limits. These cracks will also tend to increase the deflection of the member. They are even liable to expose the steel rods which if got corroded an appreciable reduction in life and strength of the member is caused. Due to these cracks which are often assumed to develop up to the neutral axis, at sections near the maximum bending moment, the area of concrete on the tension side is to be omitted from computations. Also for a reinforced concrete water tank where perfect water-tightness is required these cracks reduce the thickness of the impermeable concrete.

Low tensile strength of concrete also means its poor resistance against shear. In a reinforced concrete beam of long span greater shear stresses are developed due to its own dead weight and this necessitates provision of special shear reinforcements. These are days when acute shortages of steel are felt in many countries. Hence if concrete can be made to stand greater tension by prestressing, a considerable reduction in steel reinforcements is ensured. Again, due to low tensile strength of concrete an ordinary reinforced concrete member has only a limited resistance. Hence a single instance of overstressing the member under any unavoidable circumstance will result in a permanent deformation making the structure unsafe for any further use. Remarkable remedies for all such draw-backs are best effected by the process of prestressing the concrete.

Principle of prestressing Concrete:

Let us imagine a row of books carried horizontally by supports at ends. The tension produced at bottom due to weight of books will make each book to fall past the other one. Now, if an initial compressive force greater than the tension developed is applied by pressing with hands the lower ends of the horizontal row of books, then all the books can be carried safe. Similarly if an initial compressive force is induced in the concrete to a magnitude greater than the tensile force likely to be produced by the dead and live loads and due to shrinkage and creep of concrete, the resultant stress on loading of the concrete beam will only be compressive. This will eliminate any possibility of developement of cracks due to tension creep or shrinkage of concrete. All evils following the low tensile strength of concrete will also be averted. This is the basic principle underlying the use of prestressing causes an initial upward deflection which will reduce the resultant deflection on application of loads.

A brief history of the development of prestressing:

During the early days of the use of reinforced concrete prestressing was resorted to by lightening the reinforcements for strengthening the member, but never considering the degree of prestressing.

In 1896 J. Mandl, an Austrian Engineer first expressed the idea of counteracting the tensile strains under loads by prestress. M. Koenen, a German in 1907 derived a formula for the magnitude of the pretensioning required to limit to a certain extent the tensile stress developed in concrete. G. R. Stiener, an American Engineer in 1908 proposed to tighten the reinforcing rods first against green concrete and then to increase the tension after hardening of the concrete. In all these cases losses of the prestressing due to creep and shrinkage of concrete were not considered; and the magnitudes of prestressings applied were too low to produce any satisfactory result.

It was R. H. Dill of U. S. A. who in 1923—25 brought forward the proposal of prestressing to a magnitude sufficient to completely eliminate all possible tensile forces in concrete under working loads taking into consideration shrinkage and creep.

In Dill's system of "Post-tensioning" where any bond between concrete and steel is prevented by coating the latter with a plastic material, and thereby avoiding loss of prestressing to a great extent, a crackless concrete free from any tension was promulgated. The special advantage of using hard steel or steel of high elastic limit and ultimate strength was also suggested by Dill.

In 1928, the French Engineer Freyssinet started his scheme for creating from concrete a new homogeneous material unsing high tensile steels well bonded to concrete. He allowed a prestress of very great magnitude that even after losses of prestress by creep and shrinkage, the residual tensioning was sufficient to exert a permanent compression in concrete. If was Freyssinet who first recognised the importance of creep in concrete.

In 1938, Hoyer of Germany introduced super high strength wire (plano or string wire) and suggested prefabrication of prestressed members in long continuous runs which could be cut at site for use to required lengths just like members of any other homogeneous material.

In the light of the systems of prestressing adopted by these authorities, the methods of prestressing are discussed below in detail.

Methods of prestressing:

The only practical means now adopted for precompressing concrete is by tensioning the steel reinforcements which transmits the required compression to concrete.

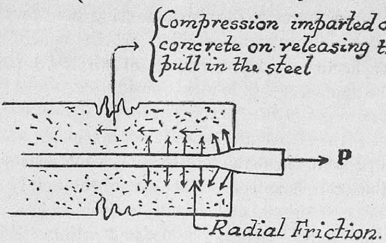
Pretensioning:

In one method, the steel reinforcements running through the mould intended to hold concrete are subjected to tension against end anchorages. Concrete is next introduced into the mould. After the concrete sets and attains requisite compressive strength and bond resistance the steel wires or rods are severed from the anchorages, thereby releasing the tensile forces to impart compression upon the concrete. Within the concrete, due to extension caused by the pull there is a reduction in the sectional area of the rod. Hence on either end of a reinforcement a wedge is formed. Transmission of stress from rod to concrete is effected by bond resistance and friction. (Please vide sketch 1). The higher the tension applied to reinforcements, the smaller will be their diameters and proportionately greater will be the bond-resistance afforded. This method is often referred to as "pre-tensioning".

Mild steels unsuitable for imparting a permanent prestress:

Let us consider a prestressed concrete beam of 50′—0″ span reinforced with ordinary mild or semi mild steels. If the steels are pretensioned to a magnitude

PRE-STRESS WITH "PRE-TENSIONING"
(By Bond & friction)



SKETCH 1

of 15,000 lbs. per square inch, assuming a Modulus of elasticity of 30×10^6 lbs per square inch, the extension in the rods available to impart compression on the concrete will be only 0·3 inches. But considering the decrease in length of the concrete beam due to creep and shrinkage of concrete, it is quite evident that within the first few months, nothing will be left of the prestress imparted by 0·3 inch extension in steels. In other words the extension in steels which is the only source of precompression on concrete gradually disappears within the course of first few months when creep and shrinkage of concrete take effect and the grip of steel on concrete is loosened. Hence with mild steels we cannot establish an effective permanent prestress.

Use of high tensile steels:

As already mentioned it was Freyssinet who first took up the scheme of using high tensile steels well bonded to concrete.

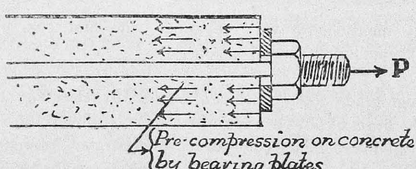
Using a high grade steel which can be initially stressed to 120,000 lbs. per square inch in the beam of 50′—0″ span which we considered, an elongation of 2·5 inches will be available to induce compression to concrete. Assuming the reduction in length of concrete due to shrinkage and creep 0·3″ (same as before), a permanent elongation of 2·2 inches will still be available. In other words the loss in prestress will be only about 12 per cent.

At present high tensile steels which can stand a safe working stress of 120,000 lbs per square inch and more are available in the form of cold-drawn wires of $\frac{3}{16}$ inch. diameter. Hence instead of singular rods, as used in ordinary reinforced concrete, a cable of a number of such wires are to be used. For proper bonding these wires are placed in a sheet steel tube. After completion of prestressing, cement grout is injected in the tube. This process not only protects the wires against rust but also ensuresa satisfactory bond with concrete. The cables of such prestressed wires are placed to follow aparabolic shape, so that at mid-span they are close to the lower fibres of the beam or slab, but towards supports they are lifted up. This is to prevent any cracking of the concrete due to tension developed towards upper fibres. A prestressing of up to 75 per cent of ultimate stress of steels can be applied.

" Post-tensioning " :

Another method is to place the prestressing cables outside the concrete. For example, the cables can be kept on either side of the web of a concrete I beam and can be passed through special end blocks against which anchorages will be applied. Or, the prestressing steels can be located within the concrete member itself, but the steels are prevented from adhering to the concrete. This is done by coating the steels with grease or asphalt or wrapping them in oiled paper so that there is no bond at all between steel and concrete. In this method concrete is poured in the moulds with unstressed steels kept in position, and after the concrete has sufficiently set and hardened, the steels are stressed by pull at their ends Hence this process of prestressing is referred to as "post-tensioning." Here due to absence of any bond, the steel can slip freely from the concrete, but the bearing plants at ends cause the concrete to be compressed proportionate to the magnitude of tension induced in the steels. Vide sketch 2.

Pre-stress with "Post-tensioning"
(By Bearing Plate)
(No bond between steel & concrete)



SKETCH 2

In "pretensioning" where the steels are installed and stressed before tha concrete is poured, on releasing the prestressing mechanism and the bearing plates the original prestress in the steel is to some extent reduced. This loss does not occur in "post-tensioning."

Prestressing ensures savings in steels:

On testing a concrete beam prestressed with high tensile wires cracks at about 70% of the ultimate load. On final loading the beam failed with a marked detonation due to snapping of all reinforcements. The ultimate tensile stress reached by these wires at fracture is usually found to be greater than the theoretical maximum stress. This might be due to the strain hardening property of the wires due to their initial stretching. Hence in the case of a prestressed member unlike that of an ordinary reinforced concrete member it is the ultimate tensile strength and not the yield strength that forms the basis of design for the area of reinforcements required. Hence using reinforcements of high tensile strengths of 100 to 130 tons per square inch and adopting factor of safety of 2 to 2·5 on ultimate strength, only 12 to 16 per cent of steel a area reqnired for ordinary R. C. member will be sufficient for members sufficiently prestressed with high tensile steels.

Prestressed pipes:

M. Freyssinet has developed reinforced concrete pipe of high strength and resilience. The consistency and mix of the concrete were arrived at with great care. Circular steel reinforcements were provided in the form intended for the pipe. Keeping the outer wall of the form rigid the inner wall is expanded. Thus, the concrete is compressed and some excess water is drained off. Then the outer form is expanded and inner form allowed to follow it so that the pressure on the concrete is maintained. Due to this expansion of the form, reinforcements are elongated until a predetermined tensile stress is induced in the steel. The concrete is then hardened at a temperature of 180° F. The concrete thus produced has a compressive strength of as high as 7000 to 8000 lbs. per square inch. After sufficient hardening of concrete, when the inner form is collapsed the tension in the steel causes the concrete pipe to reduce slightly in diameter and thereby imparting a precompression to concrete. This pipe can stand a high internal pressure; for upto a sufficiently high pressure any tension developed in the concrete will be counter acted by the precompression. Any cracking of the pipe due to working internal pressure or creep and shrinkage of concrete will be eliminated, thus keeping the pipe perfectly impermeable.

Prestressed circular water tanks:

The concrete walls of a water tank are precompressed to prevent cracks due to tension developed in concrete. The reinforcing bars are joined by turnbuckles and form bands or continuous helices around the tank wall and they are placed on the outside of the concrete; and the turn buckles are rotated for tensioning the steels. After stressing the steels sufficiently, the steel is covered with a layer of concrete. There will be no stresses in this covering layer of concrete bofore shrinkage and creep take effect. Due to shrinkage and creep, the compression induced owing to slight reduction in diameter can to certain extent nullify the tensile forces due to internal water pressure.

Certain other applications of prestressed concrete:

The process of "pretensioning" is in general adopted only for precast concrete. Hence the weight and size of such units are limited due to transport difficulties. But by adopting suitable methods of "post-tensioning" possibility of economical construction of heavy engineering units have been well established. In Germany during war time girders of upto 143 feet length and 8 feet depth were manufactured. The constructions were not economical, but they effected considerable savings in steel which was a vital consideration during the wartime. These beams were manufactured in stages according to Freyssinet process. Factory methods were also employed in Germany for production of parabolic shaped beams of spans varying from 27 feet to 96 feet and these were produced at their full lengths in one step. In Belgium prestressed concrete has been adopted for many factories For example, a textile works in Ghent, the main girder of 69′ 4″ span and 12 ft. depth were of prestressed concrete. For an air craft hanger in Brussels, the construction of which is now in progress, box shaped prestressed concrete girders of 166 ft. 8 in. span and 8 ft. 4 in. depth have been proposed.

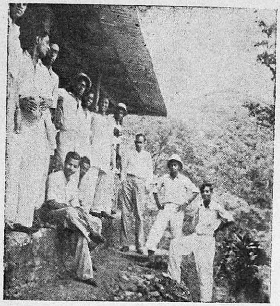
During war time in Yugoslavia and Stockholm factories were erected for manufacture of precast prestressed concrete units based on 'Hoyer Method.' At Malmo, a bus garage had secondary beams of about 60 feet length, and other beams supporting roof slabs, constructed of prestressed concrete according to 'Hoyer method.' This form of prestressed concrete was also adopted for mass production of poles for carrying over-head transmission lines.

M. Freyssinet was conducting researches on use of prestressed reinforced concrete for aeroplane runways. Two abutments anchored to the ground were to provide requisite anchorage to the runway slab of 6½ inches thickness. Steel wires of yield stress 200,000 lbs. per square inch and not bonded to concrete were provided perpendicular to the axis of the runway. By tensioning these wires against the abutment anchorages requisite compression to concrete is induced. Expansion of the slabs due to temperature will only slightly increase the existing tension in the slabs. But any cracking of the concrete due to shrinkage and creep is absolutely prevented. For the research purpose, the measurements of the stresses developed in the runway slabs were made by special instruments operating on acoustic principles.

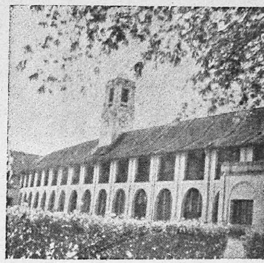
Prestressed Concrete Railway Sleepers:

The railway tracks across vast areas of Europe and Asia during the war have been torn up by high explosives and deteriorated due to over-straining and

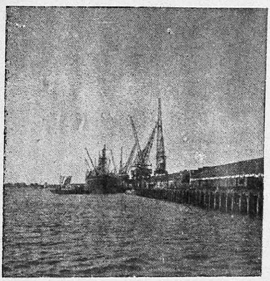
IV CIVILS AT COCHIN



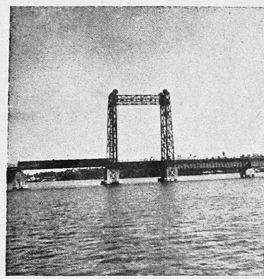
...These Young men



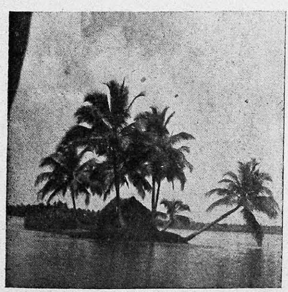
...At Cochin Port



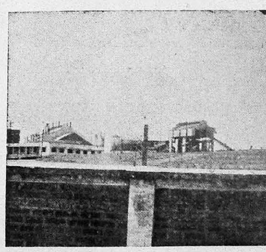
...Could see the



...Surging sea fettered

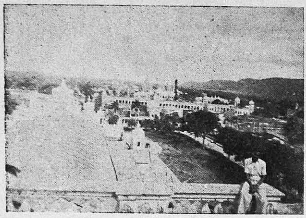


...And Nature galore with

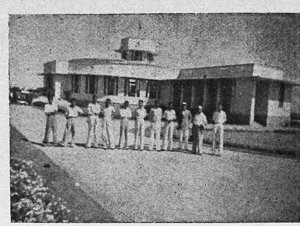


...The triumphs of man

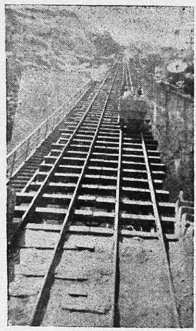
IV ELECTRICALS IN MYSORE



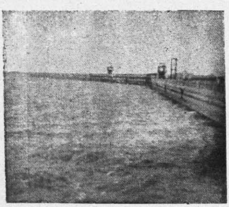
...At Mysore they saw



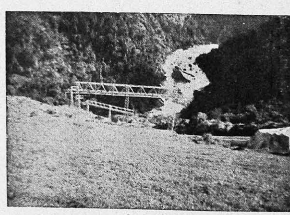
...The Akashvani



...And at Jog



...After Krishnarajasagar



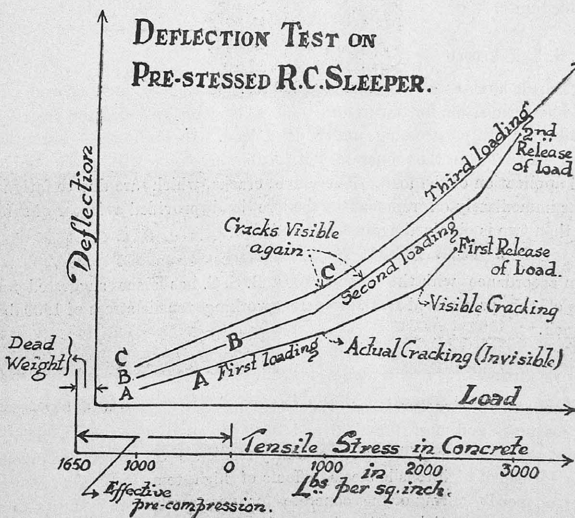
...Man Conquering

...Wild Nature

want of timely repairs. The railway sleepers are mostly of timber. Inadequate availability of suitable quality of timber forced the railway engineers to consider the possibility of using concrete to replace timber. Concrete lacks elasticity and resilience. Also the stresses caused by heavy fast-running trains are different from these due to static loads. Now a most satisfactory solution of the problem has been found in the use of prestressed concrete with special qualities of extraordinary resilience, strength, permanency, resistance to weather changes and resistance to cracks. Now at Lincolnative there is a well equipped factory for the production of the prestressed concrete sleepers.

Deflection Test on the Sleepers:

Only certain very important observations made during the tests on prestressed R. C. sleepers conducted by L. N. E. R. are briefly given below. The test comprised of **3** stages (a) Direct loading up to 50% of ultimate load and releasing the load (b) reloading the same beam up to 70 to 90 per cent of ultimate load and releasing and (c) reloading up to failure. The load deflection curves are indicated by A. B. and C in sketch 3.



SKETCH 3.

Upto actual cracking curve A was found to be parallel with the theoretical value for a homogeneous section obtained for a modular ratio of 7. When fine hair cracks invisible to the naked eye occurred, a change in inclination of curve was noted. At this stage the tensile stress developed in the concrete was 900 lbs. per square inch. The cracks developed and became visible at a stress of 1800 lbs. per sq. inch. Upto cracking curves B and C are approximately parallel to A. The cracks which were quite visible under loading completely closed up and disappeared on releasing the load, thus indicating the extra-ordinary resilience of prestressed reinforced concrete. The crack had a width of 0·01 inch (a width usually permissible in ordinary R. C. members) only at about 70% of the ultimate load; thus showing that a factor of safety of 2·0 to 2·5 on ultimate strength, is quite sufficient for such prestressed members.

According to B. S. S. No. 986/1945 for concrete railway sleepers permissible compressive and tensile stresses for concrete are 3000 lbs. & 300 lbs. per square inch respectively. A much higher tensile value is quite permissible provided there is no fatigue due to stress reversals, for, the test results showed that the width of cracks developed even at a tensile stress of 2000 lbs. per square inch is within permissible limits.

As per L. N. E. R. Report:

"Tensile stresses of 600 lbs. to 1200 lbs. per square inch or even higher appear to be permissible for structures such as bridges provided the design fulfils the condition of full prestressing under dead load. In such cases instantaneous tensile stresses occur in the concrete, but visible cracking will appear only after repeated application of the load. These five cracks which are due to fatigue will disappear immediately on removal of the live load provided a factor of safety of not less than two is obtained against failure."

In accordance with the above report B. S. S. has since suggested for the concrete of the prestressed R. C. sleepers a working tensile stress of 1200 lbs. per square inch.

Scope for research:

Amongst all structural materials the pressed concrete with its various striking features, and most practical and economical applications affords a very wide scope for research. The extraordinary resilience of prestressed members, necessity for use of high tensile steels, effects of high temperature on such steels, necessity of speedy curing of the concrete for prestressing and effects of steam curing on concrete, partial prestressing and its économy in certain cases, concrete with pretensioned and nontensioned steels used side by side and various other important and interesting topics related to the subject are being explored by research. A thorough investigation of the subject with its special features and implications are bound to revolutionise the entire present-day structural fabrications.

Conclusion :

Though the first proposal of prestressing concrete was made sixty years ago, it is only ten years back since economical methods of prestressing were introduced. Though the principle of prestressing is so simple and logical and its use so practical and economical it is a pity that the subject yet remains unknown to many engineeers. In India not a single instance of any prestressed concrete construction is so far known. A research station in India for conducting researches on prestressed concrete and its suitability for irrigation structures is of utmost importance.

References :

(1) " Civil Engineer " Magazines.

(2) "Reinforced concrete structures" by Peabody.

WORLD'S FIRST ALUMINIUM ALLOY BAS-CULE BRIDGE

The bridge was opened on November 26, 1948 at the Port of Sunderland. This is of the double leaf trunnion bas-cule type designed to carry road and rail traffic. The movable span is of aluminium alloy and weighed only $51\frac{1}{2}$ tons. The light weight enables easier movement of the span. The fixed approach and foundation girders of the bridge are of mild steel. The clear width of the road and footways is 18′ 6 inch. and centre to centre of trunnion bearings 121 ft.

Electric Power Signalling

by

R. SREEDHAR RAO, III B. E.

Electric power signalling implies the operation of railway points and signals by electrical means, manual effort being reduced to a minimum. Though such signals are mainly used over electrified railroads they may be easily adapted for use over steam traction areas as well. Among the several advantages claimed by this system of signalling are its potentialities for accelerating train movement safely and economically by reducing the time and space interval between trains, its low cost of maintenance and the elimination of the influence of human element. Again, with signals and points operated by this means the area over which one man is able to exercise control can be greatly extended. This system of signalling is specially suited for railways over which heavy high speed trains are operated at short intervals.

For automatic operation of signals the principle of track circuiting is used. A simple type of track circuit suitable for steam railroads is shown in fig (1). Here the line is divided into sections or blocks extending upto a mile or even two miles in rare cases, each block being isolated from adjacent ones by insulated fish plates. Within each block the two rails are insulated from one another, and made electrically continuous by bonding wires that join one length of rail to the next. At one end of the block an alkaline battery, located in a manhole by the side of the track is connected across the two rails and at the other end a sensitive relay is connected also across the rails. When there is no train in the section the battery supplies current to the relay through the two rails and the signal is held in the clear position. On the passage of any rolling stock over the track the current to the relay is shunted causing the relay armature to drop breaking the local circuit which throws the signal into the " danger " aspect. The signal is locked in this position until the movement of the last van of the train departing from the block removes the short circuit, closes the relay and clears the signal.

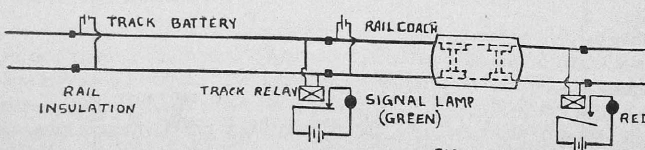


FIG (i)

Over electrified railroads using direct current, and where the running rails are used as the return path for the power current the problem becomes more difficult as the rails are no longer free for sectional insulation. A method of surmounting this difficulty is to use one rail for the return of power current, the other rail being insulated in section for signal purposes. Also alternating current may be advantageously used for the signalling relay, which would permit selective operation of it without interference from the power current. The arrangement used for this is diagramatically represented in fig (ii). As is clear from the figure, one rail called the block rail is insulated in section forming a circuit for the signal current only, the other rail constituting a common return path for the power current as well as the signal current. The alternating current for the signal circuit and for the signal lamps is supplied through step down transformers from single phase a. c. mains (500 V 60 cycles) running parallel to the track. The track circuit is worked at 10 V while the signal lamps are operated at 55 V. The power factor of the circuit is about 8 and the power taken by an average block 80 watts.

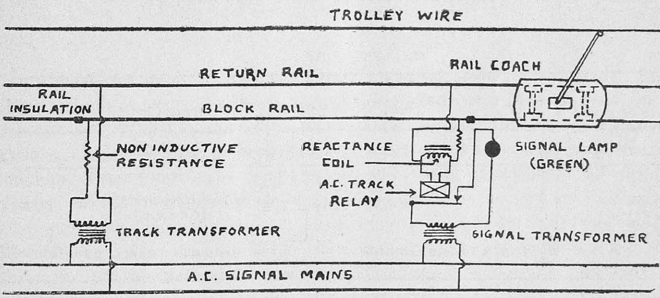


FIG (ii)

The signal circuit consisting of the block rail, the relay and the transformer secondary also forms a parallel path for the power current. To limit this direct current in the parallel path high noninductive resistances are put in series with the relay and the transformer secondary and a reactance coil is shunted across the relay. While most of the direct current will pass through this coil, the signal alternating current will pass only through the relay due to the high impedance of the coil. With these precautions the relay system operates in an exactly similar manner as in the steam road equipment.

In the case of electric railways operating with a. c. in the track rails the problem of equipping them with signals becomes still more difficult. This however is being solved by development of two rail signal system using "impedance bonds".

Nowadays this type of installation is adopted for both alternating and direct current railways. The principle of this type of signalling system is illustrated in fig. (iii). Here also both the rails are insulated at the ends of the block and an impedance bond consisting of a few turns of heavy gauge copper on a massive core and of sufficient current carrying capacity for the traction current is connected across both ends of the section. The middle points of the adjacent bonds are connected together, so that there is a complete electrical circuit from train to power house by each rail. If direct current is used for traction, it can freely pass through this impedance, because there will be no inductive effect, due to the steady current, and the resistance is low. If a. c is used for power, the connection tends to neutralize any e. m. f. in the coil due to the varying current. Even if the currents in the two rails are slightly out of balance, this e. m. f. would not be appreciable at the frequency at which the train motors operate, viz. 25 cycles. But the impedance of it will be sufficiently great to produce a useful potential difference between the rails in the signal circuit which is operated at 50 or 60 cycles. With slight modifications, this circuit works just as in a single rail design.

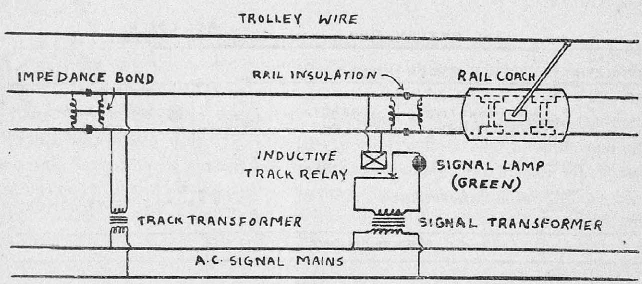


FIG (iii)

The continuous track circuit signals described above are suitable only for double track roads with no points or crossings. On a single track road the block signal must guard against both following and opposing movements. The principle of operation of these signals being similar to the double track system with slight difference only in the arrangement of apparatus, will not be discussed. Where the track is complicated by points and crossings, this type of automatic signalling cannot be used. Here controlled signals working in conjunction with interlocking apparatus is employed. The work of the signal man is further assisted by a variety of ingenious devices prominent among which is the illuminated track diagram which gives at a glance which sections of the line are occupied and which are not.

Now a few words may be written about the different types of automatic signals. They are usually either of the semaphore type or the colour light type. In the semaphore type of signals there are two classes. There are the lower quadrant and the upper quadrant signals. In the former type the signal arm drops 45 degrees to indicate line clear. The advantages of the upper quadrant signals are that it will drop to a horizontal position signifying danger should there be any failure in the electrical working of the system, and secondly such an arm gives a clearer indication to the driver than the lower quadrant type. For operating these signals a motor or a solenoid is used, the latter alternative being discontinuous due to the large current involved. The driving motor is coupled to the spindle carrying the semaphore through a gear train. A hold off magnet is used to retain the arm in the clear position after the motor has completed its movement and been de-energized.

The colour signal which was at first used only in tunnels and at nights are now often used for day light signalling also. By using special type of lenses which do not reflect sun light, and fitted with cowls to shade them, they are visible 1000 yards even in strong sun light.

The foregoing outlines standard power signalling practice upto recent times. These systems of signalling are in vogue in India over the electrified sections of railways, and to a little extent over steam railroads as well especially in junction stations. In the last few years considerable progress has been made in the field of power signalling loading upto new systems, but it will be sometime before such systems will come into practice in our country.

References:

(i) Electric Railway Engineering by Harding.

(ii) The Metropolitan Vickers Gazette October 1946.

(iii) How it works and how it's Done—Home Library Club.

PELTON WHEELS.

Pelton wheels have been used upto heads of more than 1 mile. Chandoline plant, Switzerland has three Pelton wheels of 50,000 h. p. each under 5740 ft. head.

Building Materials

by

V. D. MUTHAYYA, M. SC., Asst. Lecturer in Geology

Building construction dates from a very early period in humam history. With the progress of civilization of man and the increase in his knowledge of mineral kingdom, new structures and modes of construction in buildings, have been introduced from time to time.

Buildings of huge and grandiose structures seem to have been the fascination of the people in very early times. As for example, we have the great pyramids of Egypt built about 3000 years ago, during the ancient Egyptian civilization. Later beauty followed grandeur and the artistic skill has been displayed to a very great degree in the buildings of the period from tenth century onwards as in the magnificient temples and palaces of India and the exquisite Cathedrals of Europe built during the Elizebethan times. Coming to the modern era, we find that utility follows beauty.

Present day structural and building operations consume large amounts of minerals and mineral products besides the various kinds of building stones.

The chief building materials used now are as follows :—

Building, roofing and crushed stones.

Hydraulic cements.

Building sand and gravel.

Gypsum.

Lime.

Magnesite.

Mineral pigments.

Asbestos.

Clays.

Building Stones :

These include the various kinds of rocks which are dressed and trimmed to proper shapes and utilised for construction and ornamentation purposes. For a good building stone certain geological and physical properties are necessary, such as, pleasing appearance, durability, and ease of processing and quarrying.

Geological knowledge is useful in the selection of stones suitable for various purposes such as the construction of dams, bridges, buildings etc. It also helps a great deal for easy procurement of building stones from the very locality or near by area where the constructions have to be carried out, by knowing the geological formations of that place, thereby avoiding unnecessary cost of transport of buildingstones from a far off place.

For determining the suitability and durability of rocks for buildings, their mineralogical composition should be known. The minerals like chert, mica, pyrite etc., are injurious and harmful and their presence should be avoided. The stones containing minerals like pyrite that oxidise and produce unsightly stains are undesirable. The fine-grained rocks will be stronger than one which is coarse-grained. The durability of a stone is its capacity for retaining its original size, strength and appearance for a long period and this depends upon its capacity to withstand the weathering conditions ie. the action of atmosphere, rain etc.

For selection of good building stone, the other properties like absorption, crushing strength, fire-resistance, resistance to weathering should also be tested in the laboratory.

The common rock types which are used in buildings and other constructions are granites and related igneous rocks, limestone, marble, slate, sandstone, soapstone etc.

Among the igneous rocks mostly granites and gneisses are used. Granites are used on account of their even granular texture, pleasing colour, and favourable physical properties like high crushing strength, low absorption suited for the purpose. They can be easily quarried on account of certain well developed joints and divisional planes. They are available in all parts of the country and in large amounts. Basalts and dolerites are not usually preferred for building purposes because of their dark and dull colours. Sandstones and quartzites which are of abundant occurrence are also used for building purposes. Quartzite is not usually used in masonry because of its extreme hardness which renders working difficult. Limestones can be quarried easily and they are chiefly used for buildings because of their light and pleasing colours. Marbles and ophicalcites are used for decorative work in buildings. Basalts, dolerites and quartzites serve as excellent road metals though not much favoured as building-stones.

Buildingstones of India :

Granites and gnanitic gneisses available in plenty in the Archacan rocks of India have been used in the construction of most of the temples and public edifices in Southern India. Charnockite a variety of granite serves as an excellent building stone and out of this rock are hewn out the seven pagodas at Mahabalipuram near Madras. The Vindhyan sandstones and sandstones of other older formations are used extensively as building stone in India. The Budhist stupas of

Sarnath, Barhut, Sandi, Emperor Akbar's City of Fatehpur Sikri near Agra and the famous Moghul buildings at Agra, Delhi and Lahore and the modern administrative offices of the Government of India at New Delhi have all used Vindhyan sandstone in their construction. Vindhyan sandstones are also used as flag-stones for flooring and roofing, window-sills, telegraph poles, milestones etc. Another variety of sandstone of great beauty and durability is the Athgarh sandstone obtained from the upper Gondwana rocks in Orissa. The celebrated temples of Puri Jagannath, Bhuvaneshwar, Konar and the Buddhist caves at Kandagiri and Udayagiri have been hewn out of these sandstones. Limestones which serve as excellent building and ornamental stone are found in most of the Geological formations in India. The world famous Taj-Mahal has been built up of the Makrana marble of Archaean Dharwars. The limestones from Guntur and Kurnool districts are capable of yielding excellent buildingstones. The limestones quarried near Yerraguntla (Cuddapah Dt.) and near Betamcherla (Kurnool Dt.) and popularly known in the Madras presidency as 'Cuddapah slabs' are widely used as paving stones, fence stones, steps and table tops. They are capable of taking a fairly good polish and can be split into slabs, half an inch or more in thickness and up to 6 ft. by 4 ft. in size. Laterite which occurs extensively, along the west coast of Malabar, Central Provinces and other places in India serve as a fairly good and durable building stone from the facility with which they are cut into bricks or blocks when freshly quarried and their property of hardening with exposure to air. It is used also as a road-metal because of its abundant occurrence.

Roofing Stones:

Slate, a kind of metamorphic rock which can be split evenly and into thin layers is used chiefly for roofing and paving in buildings. Slates are quarried in India near Dharmsala in Kangra district, Kund in Gurgaon district, Monghyr in Bihar and Markapur on the Nellore–Kurnool border.

Crushed stones:

With the introduction of use of cement concrete in buildings and other constructions rocks are broken into aggregates called crushed stones and used largely for cement concrete. The rocks used are, Granite, Basalt, quartzite etc. Basalts available in plenty from the Deccan traps of Bombay, Kathiawar, Cutch, Central Provinces, India and Central India are excellent for use as aggregates in cement concrete because of their toughness and good binding properties.

Hydraulic cements:

The vast expansion of high way and building construction created great demand for cement and the industry is now one of the largest amongst mineral industries. Cement is a manufactured material and is essentially a mixture of four parts of limestone and one of clay or shale, calcined to near fusion and ground to a powder.

Portland cement was discovered by Aspdin in England in 1824 and named by him because it resembled the famous Portland stone.

The combinations of raw materials used are, (1) Limestone with clay or shale (2) Blast furnace slag and limestone. (3) Marl and clay. (4) Oyster shells and clay.

The raw materials for cement are all available in abundance in India. The limestones of the Vindhyan formations are amongst the most important sources of raw materials for the lime and cement industry in India. The small amount of gypsum necessary, 2 to 3 percent, comes from Khewra in Punjab, Jodhpur state and Trichinopoly in Madras. Gypsum is added to the cement mixture before final grinding to prevent too rapid setting.

The principal cement producing centres are, Porbandar in Kathiawar, Katni in C. P, Bihar, Guntur, and Trichinopoly in Madras. At present there are about 20 companies in operation, with a production of over million tons annually.

The vast reserves of Bauxite and Magnesite in India will serve as invaluable raw materials in the manufacture of special cements.

Sand and gravel :

They are essential in modern construction, particularly in paving and building. They are widely distributed the world over and occur as fluvio-glacial deposits, stream-channel and flood-plain deposits along and near bodies of water, as desert sand dunes and as marine and fresh water sedimentary beds. There are also special sands which are made use of in glass, ceramics, abrasive and other industries.

Gypsum :

Gypsum or the hydrous calcium sulphate is one of the most important non-metallic minerals. It was known and praised by the Assyrians and Egyptians for making containers and for sculpturing. There are several varieties of gypsum—the glassy crystals of selenite, the fibrous or satin gypsum, the massive fine-grained translucent alabaster, and the common granular textured massive beds of gypsum. It is used for a great variety of purposes from an ornamental stone to the calcined 'plaster of paris' cement, also pigments as 'mineral white' as a paper-filler and in agriculutre as a fertilizer.

India has enormous reserves of the common massive gypsum in Rajputana, the Punjab, and North-western India generally and in Madras (Trichinopoly). Jodhpur, Trichinopoly and Bikaner are the three chief producing areas. The production since 1937 has varied from 46,000 tons to more than 78,000 tons annually. India could produce still much larger quantities.

Lime :

Since the time of the ancients, lime has been used for mortar. It is simple and cheap to prepare. Limestone or the calcareous rock is heated in kilns when the co_2 is driven off and quick lime remains. This slakes with water and mixed with sand it makes mortar or plaster. Magnesia lime makes a strong, hard, elastic stucco. (Stucco—a plaster of lime and fine sand etc. used as a coating for walls, for decorations etc.)

Since the raw materials for lime are worldwide in distribution, it is produced almost everywhere according to its need.

Magnesite :

Magnesite or the natural magnesium carbonate is the chief source of magnesia (Magnesium Oxide.)—both the caustic magnesia, and the dead burnt magnesia. Caustic Magnesia (Calcined at about 1000° c and retaining 3 percent of its co_2) mixed with magnesium chloride forms the basis of the very valuable Oxy-chloride or Sorel Cements used in patent-flooring, artificial stone, abrasive wheels etc. Dead-burnt magnesia is relatively inert and not easily disintegrated even by great heat and thus finds use as a furnace lining for lead and copper smelting furnaces.

Magnesite occurs in large deposits in the Salem district of Madras and Mysore. The Indian production of magnesite chiefly from the chalk hills in the Salem district of Madras, has increased from 25,000 tons in 1937 to 40,000 tons in 1941 with the increase in the use of metal magnesium in the preparation of light alloys with aluminium and in incendiary bombs.

Mineral pigments :

Minerals as ingredients in paints have come to be used since very early times. Limonite, hæmatite with or without mixtures of clays and manganese oxides known as ochres, under, sienna were used as natural paints by the pimitive race for decoration and drawings.

Now the paint industry absorbs a great variety of minerals in the manufacture of different coloured paints. Minerals employed at present in the manufacture of paints are chiefly, Barytes, celestite, graphite, ilmenite sand, red and yellow ochres, chromite, lead and zinc ores.

India is rich in these minerals except for lead and zinc ores.

Asbestos :

This being a highly heat and fire resisting material has come to be used largely in the building materials, as asbestos cement, sheet-roofing wall-boards etc. Only the long fibred, less flexible tremolitic variety is used for this purpose. They are available in India from Saraikala state, Mysore, Rajputuna and Singhbhum.

Clays:

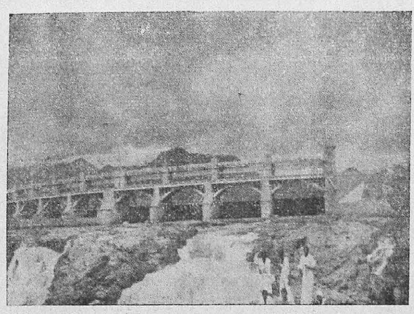
They are extensively used in the manufacture of bricks, tiles and other building materials. Special types of clay like kaolin or china-clay and fire-clay find their use in porcelain industry and in the manufacture of refractories respectively.

The common or lower grade variety of clays useful in pottery and brick making materials is available in plenty from the river-plains of India.

Kaolin or china clay occurs in thick extensive beds as a decomposed product of felspars in granites. They are available in India from Bhagalpur, Singhbhum, Delhi, Belgaum, and various places in Mysore.

Fire-clays are chiefly got from Jubbulpore, Raniganj and the Garo-hills in Assam.

In the preceding paragraphs a complete picture of the present day building materials and their availability in India has been portrayed and in conclusion it may be said that the vast reserves of road and building stones and raw materials for cement, lime, concrete. paints etc., in India have not been utilised to the extent that their supply could easily provide for.



"It's Just A Mamool, Sir!"

by

F. H. ENGINEER, III B. E. (Civil).

Scratching his head, the tahsildar leant back. With a puzzled frown he took up the manuscript in front of him and mused. "My hero has plumbed the depths of contrition. Aching to ease his conscience he contemplates suicide. Should he, or should he not jump into the raging flood waters? Perhaps, if I read my story over again, I could arrive at a fitting conclusion."

Unlike most other tahsildars, he had a literary bent of mind and short story writing was his chief hobby. So he adjusted his spectacles and with an old man's pardonable pride slowly read through his story.

'We the Engineers will put the world on its feet again', Prakash Rao had said and his lawyer friend had smiled. Prakash was young then. He had just graduated as a Civil Engineer with a right to insert a 'B. E.' after his name. Young and enthusiastic and confident to put his knowledge to practice, his appointment as a supervisor in the P. W. D. had elated him.

'Yes, you are lucky to get a job so soon. But you will have to work very hard and the start is not so good', his lawyer friend had said.

"Oh, that's all right. If I work hard I earn my promotion'; and with a laugh 'I am going to impress my superiors, you know.'

'Governments move slow,' was the lawyer's dry comment, and Prakash thought, that as a lawyer, he had to be critical.

* * * *

"Years passed on, and Prakash had supervised the setting of tons of cement and had surveyed much land. He really worked hard."

"But, after eight years, when Prakash sat back for a moment and took stock of his position, a black wave of disappointment washed into his soul. His rise in the P. W. D. had not been on a par with his eight long years of sincere service—years spent with patient devotion to duty, out in the blue, in places desolate and uninhabited. Also his younger sister, who had hitherto presented no problem, now loomed large on his mind. She had passed her teens, and Prakash realised with sickening apprehension that he had no savings whatsoever to give her away in marriage. In the back of his brains he felt the blazing tongues of despair. All these years he had merely existed and not lived. Impecuniority is an impassable barrier to society and Prakash had no hope of fulfilling his fond desire of seeing off his sister happy.

"Later, Prakash was put in charge of a major work of remodelling the flood banks of the 'Thenar' Anicut including construction of a number of new groynes in the margin—consequent on raising of the anicut crest. By this time Prakash knew the ins and outs of all such works and he had never so far budged an inch from strict supervision. But, here for the first time he 'gave in' to the contractor, who with a cunning born of long practice worked on Prakash's morals which were now pliable due to his frustrations and desires. Using methods which are only too well known, the contractor succeeded in coming to a tacit agreement. whereby he could use inferior materials towards the construction and Prakash would receive a slice of ill-gotten gains. For the contractor it was almost a routine; but, for Prakash who had hitherto been a rigorous officer, it was new. Though, a deep sense of guilt abided in him, imbued with the sole idea of making his sister happy, Prakash accepted the situation as inevitable.

"The construction was over towards the close of summer. Shortly afterwards, he saw his sister happily married. Immersed in preparations for the event, for a brief interlude, everything seemed bright to him. But soon, like the recurrence of the bad taste of a bitter almond, long after it had been spat out, a sense of disquiet possessed him. An intangible foreboding, vague yet menacing, He decided never again to stoop to corruption. He tried to forget the past and by hard work to look forward for a promising future.

"But Prakash had not considered the inexorable forces of nature. With a suddenness which made it more shocking there came a cyclone and heavy rains for three days and 'Thenar' was running full. The swollen waters soon overcame the feeble resistance put up by the rotten flood banks and a breach occurred. In no time it was a hundred yards long and was still widening. A fatal sheet of water was escaping careering madly over the country side. Thousands of cattle and scores of men and women near about were drowned. Many were rendered homeless, and the villages once flowing with milk and honey, now presented a death-like desolation. The fertile fields were silted and the year's harvest lost. What was more, was that the entire area faced the prospect of a famine for few years to come until the lands could be recovered from the overlying silt.

"Instead of gravelly soil to be used from a lead of half a mile, only the silt and sand of the river bed formed the bulk of the bank. The groynes too were only of sand covered on all sides with rough stones. Every pie he had made out of the materials had meant a reduction in the gap between a safe and unsafe construction, a gap which he had hitherto held inviolate and on which the whole tuition in the Engineering College had been based. All these, and more Prakash fully realized, and each passing moment brought forth a more vivid realization of what he had done : how a single instance of relaxing his morals followed inevitable disaster.

"Being sensitive, he now suffered from his own imagination. He had gambled on lives of innocent villagers. The crime he committed seemed too heavy to bear and slowly a conviction gripped him that his life was the forfeit.

"Far off, he could hear the villagers shouting and running towards his house to report the breach. He tore his hair and ran madly to the spot. There his head began to reel as he heard the tumultous uproar of wild waters rushing past to do its fatal destruction. For a moment it seemed to him that the water had assumed life and was laughing at him as it was wreaking vengeance on his negligence of duty. At a distance he could see the roofs of small huts being carried away to unknown places, and the dead bodies of cattle floating in whirl pools.

"The raging waters beckoned him and showed him the way he shonld expiate for his crime. A plunge and free himself of the sin! ...."

The tahsildar broke off here and looked up impatiently as his servant entered the room.

"Somebody to see you, sir. He won't give his name, but says it is private."

Wondering whom it could be, the tahsildar ordered him in. The visitor was a middle aged man whom he had never seen. He had ingratiating manners. He gave out his name as Srikant, and begged to be excused if he had disturbed the tahsildar. He then began to speak, gradually at first, on the purport of his visit, which the tahsildar had already guessed.

"You know, sir, I had a talk with er — your friend about that permit and he said to see you. You know that, er — its about my daughter's marriage. I've invited many, and with that permit I could buy the extra food stuffs." Again with a smile, "I'm very sorry to trouble you, sir, but you know how it is. We have to somehow adjust ourselves. All the while, Mr. Srikant was casting his gaze all over the room, never looking the tahsildar direct and talking with much hesitancy. He now dipped his hand into his pocket and slowly made as if to pull out his purse.

Just then, to Mr. Srikant's astonishment and confusion, the tahsildar laughed out loud and long in a manner which suggested that he was enjoying a private joke. This added to the visitor's discomfiture. Finally after much chucking he said:

"You know, Mr. Srikant, it is all so funny. Just before you came in I was reading my short story which is almost complete — a story of an Engineer's dealing with a Contractor"—and here he looked meaningly at his visitor and "an Engineer who seeks to arrange h is sister's marriage .... Well, you will see the connection yourself. Listen!"

The tahsildar adjusted his spectacles again, and read out what he had written about Prakash. When he concluded, he looked towards his visitor who had listened to the story with signs of appreciations which changed to a frown towards the close. "Prakash needn't die". He protested with a smile.

"Please! .... Here sir!", the visitor rose up and held out his hand. "After all, it's just a mamool, sir!"

Joy Ride

*

The earth is a member of the Sun's family. The sun is jaunting along at a fairly good pace of 40,000 miles an hour, towards the constellation Hercules, not with any idea of reaching it, as Hercules is also running in space. As an inhabitant of the Earth, you are enjoying this Joy ride of 400,000,000 miles a year. Lucky, there is no corporation to collect tariff!

High Co-efficient Waste Weir

by

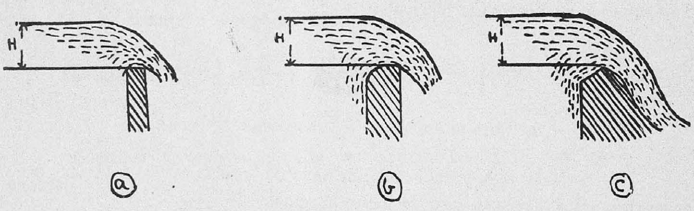
K. Venkateswara Rao, IV B. E. (Civil).

Weirs, in general, can be divided into three groups according to the shape of their crests:— (a) Sharp crested weirs; (b) Broad crested and (c) Narrow crested weirs.

The waste weir, now under discussion is of the third type, and the crest of a dam or a spill-way from a canal or a reservoir is a weir of this type.

Let us first examine, how the shape of weir crest affects the nappe form. The crest with a sharp upstream corner [shown in fig. 1 (a)] produces a contraction of nappe. Because of the narrow crest, the nappe springs clear and discharge

Fig. 1.



occurs as for a narrow crested weir. This contraction of nappe decreases the discharge. In the second case the upstream corner is rounded off, thereby eliminating the contraction of the nappe. [Vide fig. 1 (b)]. This increases the discharge. In fig. 1 (c), the upstream and downstream corners are so shaped that the nappe adheres to the faces of the weir. It is evident from the sketches that this section ensures maximum discharge, and is called the "Ogee" section.

Besides other factors controlling discharge, the effects of (1) down-stream sloping face, (2) Upstream batter and (3) height of crest above upstream bed, on discharge are discussed below based on experiments conducted by Bazin, Bellasis, Francis, Hamilton Smith etc.

(1) *Effect of downstream sloping face:* Some of Bazin's Experimental results are tabulated below.

TABLE I.

Direction of inclination	Weir vertical	Downstream face				
Slope (horizontal to vertical)	0	1 to 3	2 to 3	1 to 1	2 to 1	4 to 1
Relative discharge	1·00	1·04	1·07	1·10	1·12	1·09

It is seen from the tables that the discharge increases with the increase in downstream slope upto a limit of 2 to 1.

(2) *Effect of upstream batter:* A front face batter increases the discharge over the crest.

From experimental results on weirs with different upstream batters, a formula for the weir co-efficient is deduced. The basic equation of discharge over a weir is: $Q = c\ b\ H^{1\cdot5}$ where c = co-efficient of discharge; b = breadth of weir and H = head of water over the crest (uncorrected for velocity of approach). This equation for the weir co-efficient is :—

$$C = \left\{ 3{\cdot}62 - 0{\cdot}16\ (s-1) \right\} H^{\frac{1}{20}} \quad \text{........................(1)}$$

Where s = the slope of upstream face (horizontal to vertical)

This formula is applicable only for weirs of breadth 3 to 4·5 ft. and the downstream face shaped to keep the nappe hugging.

(3) *Effect of height of crest above upstream bed level:* Experiments conducted by Bazin, Hamilton Smith and Francis prove that increasing the height of crest above the upstream bed decreases the value of C — the weir co-efficient. M. L. Garga from a number of experiments on Sarda Canal weirs also arrived at this conclusion. However, for practical considerations this effect is not very appreciable.

The nappe may assume the following forms as the head over the crest varies :— (1) discharge freely touching only the upstream crest edge (fig. 1a); (2) adhere to top of crest (fig. 1b); (3) adhere to downstream face; (4) adhere to both top of crest and downstream face (fig. 1c); (5) remain detached and become wetted underneath, and (6) be depressed with partial vacuum beneath it. For each of the above forms there is a different relation of head to discharge. But, for an Ogee section the nappe assumes a definite form, ie. adhering to top of crest and down stream face. Hence in this section the relation of head of water to discharge is simplified and devoid of complications arising due to change of forms of nappe.

The following table based on Bazin's investigations gives relative discharges for a thin-edged weir for various conditions of nappe.

TABLE II.

Condition of Nappe	Relative Discharge
(1) Free discharge in air with full aeration ...	1·000
(2) Nappe depressed with partial vacuum beneath ...	1·060
(3) Nappe wetted underneath ...	1·148
(4) Nappe adhering to downstream face ...	1·279

This again shows that an Ogee section has a greater discharge.

The downstream face of such a weir section must approximately follow the curve which the lower surface of the nappe would form, if left to itself. So, we have to define the curve of the lower surface of nappe to arrive at the downstream face.

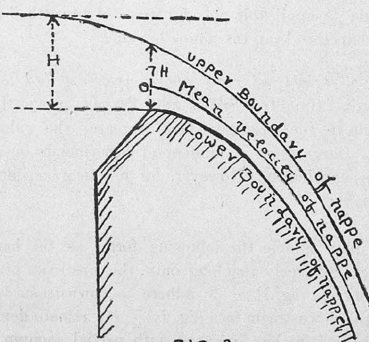


Fig. 2.

In fig. 2, is shown the upper and lower boundaries of nappe over a weir. The curve followed by the particles of water representing the mean velocity of stream may be assumed to be at $\frac{2}{3}$ the depth of nappe below its upper surface. Hence, if this curve is plotted, the curves of upper and lower boundaries of nappe can be plotted.

If Q is the quantity of water in cusecs flowing over each foot of weir, and d the depth of nappe at any point, the mean velocity at that point $= \frac{Q}{d}$ ft. per section. If V_h = velocity in horizontal direction and V_v that in vertical direction at any point, then :—

Resultant velocity at that point $= \sqrt{V^2_h + V^2_v}$. Here V_h represents the mean velocity at the overflow sill, and V_v that due to gravity at the point. Taking Francis' Formula for discharge over a foot length of weir as $Q = 3{\cdot}33\ H^{1{\cdot}5}$ (H, being the depth of "still" water to sill) and assuming the depth of water over crest to be 0·7 H :—

$$\text{Mean velocity at this point} = V_h = \frac{Q}{d} = \frac{3{\cdot}33\ H^{1{\cdot}5}}{0{\cdot}7H} = 4{\cdot}76\sqrt{H.}$$

A particle of water flowing from the overflow sill along the curve of mean velocity of nappe, at the end of 't' seconds will reach a point P whose co-ordinates (referring to ○ as origin) are :— $x = V_h\,t$; $y = \frac{1}{2}\,gt^2$. (The units being in feet and seconds).

$$\text{Then } y = \frac{g}{2} \times \frac{x^2}{V_h{}^2} = \frac{32{\cdot}2\ x^2}{2\ (4{\cdot}76)^2\ H} = \frac{0{\cdot}711\ x^2}{H} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Hence the path traced by a particle of stream along mean velocity is a parabola of equation (2). The lower boundary of nappe can be plotted with the aid of this curve; and by actual trial and error method, the profile shown in fig. 3 is found to be most efficient.

Adopting an upstream slope of 1 to 1 in formula (1) the maximum value of $C = 3{\cdot}62\ H^{\frac{1}{20}}$. If the downstream face has a radius of 3 ft. it nearly coincides with the lower boundary of nappe and with a following slope of 1 to 1 the discharge is increased (vide table 1).

In the equation for discharge over this crest per foot width $Q = C\ H^{1{\cdot}5}$, the value of the weir co-efficient "C" can be approximately calculated from formula (1).

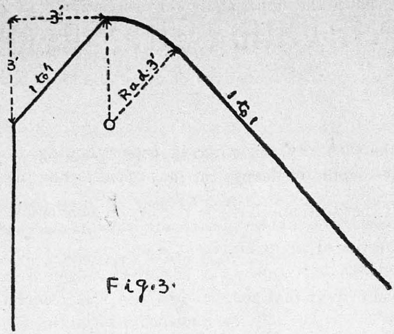


Fig. 3.

If H = 4 ft. (uncorrected for velocity of approach)

$$\text{then } C = \left\{3{\cdot}62 - {\cdot}16\ (1 - 1)\right\}\ 4^{\frac{1}{20}} = 3{\cdot}88.$$

Thus with lower heads of 0·5 ft. to 4 ft. the co-efficient of discharge lies between 3·49 to 3·88.

Hence, this type of profile is most efficient for spill-ways of overflow dams, large reservoirs and tanks.

India being a predominantly agricultural country, researches and experiments for improving and increasing the efficiencies of great irrigation structures are of utmost importance. The calibration and determination of the modular ratio of the type of weir crest discussed in this paper, can form one amongst such thousand subjects that need further investigations.

Self-Oiling Dead-Centre

◆

Range of patented self-oiling dead-centres, for general or precision lathe work, has been developed by Messrs. Austin and Ling, Limited, who have moved from their former premises on the Great West-road, Brentford, to Heather Park-drive, Wembley, Middlesex. These centres are made in sizes from No. 2 to No. 5 Morse taper, and are designed to provide a ready means of lubricating the cone end of the centre without recourse to an oil can, or relieving tailstock pressure. When needed, oil is pumped from the hollowed-out shank of the centre by finger pressure on a small spring-loaded plunger, which is set in the shank near the base of the cone. The shank is drilled axially to form a cylindrical oil container, and is filled by unscrewing an end cap and removing a suction follower which is loosely chained to the cap. The end cap is provided with an air vent which should be kept clear to allow the follower and pump to function properly. The spring-loaded plunger operates in a flooded chamber between two spring-loaded non-return ball-valves. One of the valves seals the chamber from the oil container, and the others from a narrow discharge hole which leads to a groove running down the surface of the cone from the base to the apex. When the plunger is depressed, oil is forced from the flooded valve chamber to the discharge hole; provided the centre has been fitted in the tailstock with the discharge hole approximately vertical, the expelled oil then runs down the groove towards the tip of the cone. The groove has rounded edges, so that as the work rotates an oil wedge is built up between the centre and the work, and helps to form an oil film between the bearing surfaces. If dirt or grit clogs the discharge hole, and cannot be removed by pumping, it can be cleared by a silver-steel rod, which after emptying the oil container, is inserted to pass the two ball-valves. Each dead-centre has cone surface of Stellite; this is deposited by welding, a method claimed to give a stronger job than is obtained by brazing a cast cap. —*British Information Services.*

CHRONICLE

★

COLLEGE

1. AHCTECH UNION.

The year has been the most outstanding in so far as the activities of the Union are concerned. We were honoured by visits and addresses from prominent Engineers, Ministers of the Provincial Government and other prominent men like H. E. Gen. Cariappa, Commander-in-chief, India and Sir C. P. Ramaswami Iyer.

The inaugural address of the Union was delivered by Mr. D. Rajagopalan, B. E., M. I. E., on the 2nd August 1948. In his address, Mr. Rajagopalan referred to the very many scopes that await the student Engineer.

On the 4th of August, the Union had the honour of an address by Sir C. P. Ramaswami Iyer, speaking to a packed house, he deplored the lethargic tendencies that pervade the Public Works Department and expressed the hope that in a Free India, the Engineer will guard himself against these.

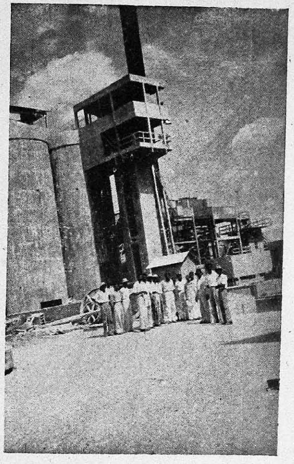
The Honourable Mr. Bhakthavatsalam, Minister for P. W. D., Govt. of Madras, expounded to the members the plans of the Government to eradicate poverty by expanding the existing projects and embarking new ones.

Independence Day was celebrated with due solemnity and reverance in remembrance of our departed father Mahatma Gandhi. Mr. R. T. Naidu spoke on the significance of Independence.

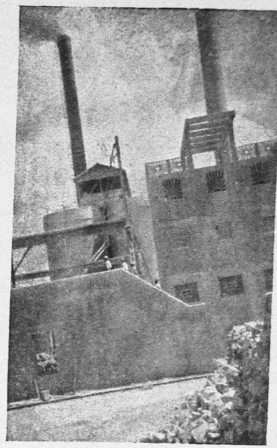
The Hon. Dr. Gurubatham, Minister for Firka Development, explained to the members the methods and the necessity of social service. A welcome surprise visit was that of Hon. Mr. Gopal Reddi, Minister for Finance. The Minister emphasised the economic and financial crisis facing the country. In the absence of the President and the Secretary, the Vice President, Mr. Fred Soans presided over the meeting and the Joint-Secretary, Mr. Balaprabudoss proposed the vote of thanks.

The 13th November brought the Collector of Coimbatore, Mr. F. W. A. Morris in our midst. In his speech, which was repeatedly applauded for its sincerity, Mr. Morris referred to the factions that exist in the villages of this country and explained how these could be remedied.

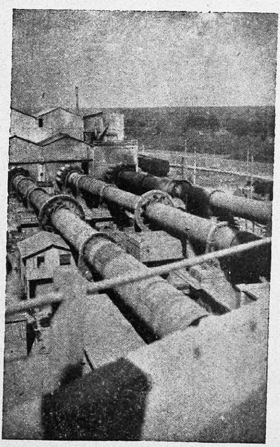
III CIVILS AT MADUKKARAI



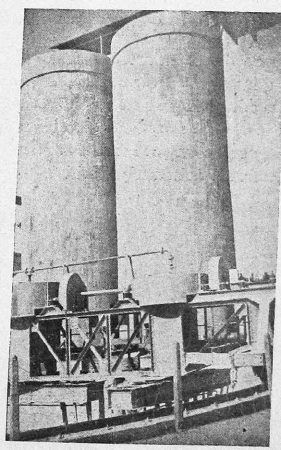
...This group saw



...The Mighty Factory, where

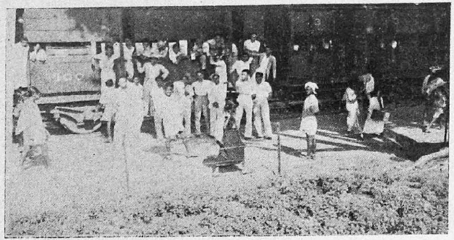


...Whirled the rotary kilns

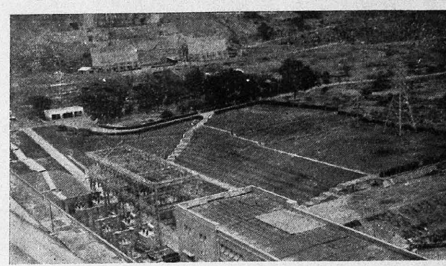


...To dump cement in these

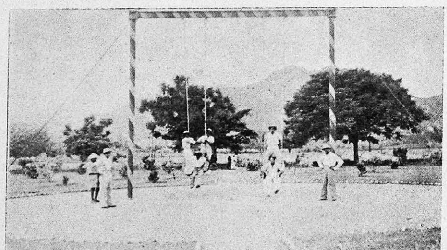
III ELECTRICALS AT METTUR



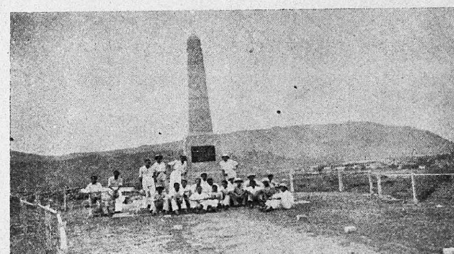
...Arrival



...The powerhouse



...Recreation



...End of the toil

We were greatly honoured next by the address of Mr. Humayun Kabir, Educational Adviser to the Government of India. Mr. Kabir spoke on the role of students in Free India.

Mr. Karantha, Chief Electrical Inspector, Govt. of Madras, spoke on Electricity and its application to our villages.

On the 2nd of February 1949, H. E. Gen. K. M. Cariappa, C-in-C. of the Indian Army, honoured us by a visit and address. Rising amidst scores of clicking cameras and terrific cheers, from a doubly-packed house. His Excellency spoke on the significance of the army and how we should co-operate with it to make the country glorious.

Such a glorious year came to an end, rather too quickly, in the sense that it was too crowded, by the Valedictory address of Sri T. R. Sundaram, B. A.,B. L., Public Prosecutor, Coimbatore. The speaker detailed to the members the cultural strength of India and explained how we could maintain it.

Apart from these meetings an Inter-Collegiate Orotorical Contest was held on the 6th November 1948. It is a matter of pride to us to mention that the first and second prizes (Books worth Rs. 25 and Rs.15) were secured by Mr. T. Somasundaram and Mr. A. Balakrishnan of this College. The third prize offered by the Union was awarded to Mr. Chandrasekhara Rao of the Agricultural College. The first two prizes were kindly donated by the Rotary Club, Coimbatore.

I must thank the patron the office-bearers and members of the Union, but for whose co-operation, such a glorious report could not have been possible.

S. PONNUSWAMY,
General Secretary.

2. CIVIL ENGINEERING ASSOCIATION

This is the first time in the annals of this College to start the Civil Engineering Association. The following office-bearers of the Association were elected on 16—7—1948. The Patron of the Association is Prof. A. Viswanath, Principal of the College.

President :	Prof. P. R. Ramaswami.
Secretary :	Mr. Ch. Rama Rao.
Treasurer :	Mr. B. G. Pattegar.

The donations by the President and other staff members, supplemented by the subscriptions from the student members formed the revenue of the Association.

With regard to the activities, the association had a number of meetings and valuable lectures were given by eminent engineers.

The inaugural address of the Association was delivered by Sri O. R. Narayanaswami, B. E., I. S. E., Superintending Engineer (Highways) on 23—7—1948.

A debate was held on 6—8—1948: The topic being "Considering the present situation in South India, Irrigation gains priority over Industry." The motion was carried.

Date	*Lecture on*	*By*
1—9—1948	"Aerodrome construction—Task of Civil Engineer."	Mr. B. Sathuram, Aviation Officer.
7—9—1948	"Pioneers that shape the nation".	Mr. A. M. Usman, B. E.
11-11—1948	Paper on "Earth pressure—a new theory".	Mr. Ch. Rama Rao, B. SC.
15-11—1948	Paper on "New profile for surplus weir".	Mr. K. Venkateswara Rao.
5—2—1949	"Irrigation Projects".	Mr. U. S. Ramasundaram, B. E., I. S. E., Superintending Engineer, P. W. D.
8—2—1949	"Highway Engineering—Government Policy—there of".	Mr. K. S. Krishnan, B. E., A. M. I. E., Divisional Engineer.
18—2—1949	Paper on "Design of balcony Girders".	Mr. S. Ponnusamy.
22—2—1949	Paper on "Water supply—Methods of filtration".	Mr. M. Ibrahim Alee Saheb.
2—3—1949	Paper on "Methods of treatment of Sewage".	Mr. S. Viswanatharaju.
5—3—1949	"Planning for prosperity".	Dr. K. Lakshmana Rao. Designs Engineer.
8—3—1949	Paper on "Survey adjustments—Theory of least squares".	Mr. N. Vasudeva Shastri, B. A.
10—3—1949	"Investigation of Irrigation Projects in South India".	Mr. T. S. Venkataraman, B. E., I. S. E., Superintending Engineer, P. W. D.
27—3—1949	"Multi-purpose projects".	Mr. A. R. Venkatachari, B. E., I. S. E., Chief Engineer, Madras.

With the kind blessings of the Patron, enthusiastic efforts of the President, and hearty co-operation from the members, the Association closed its successful activities for the year 1948—'49.

My thanks are due to all the distinguished gentlemen, who have addressed our Association.

Ch. RAMA RAO,
Secretary.

3. ELECTRICAL ENGINEERING SOCIETY

Since this year the college introduced the final year course in Electrical Engineering, the necessity for an association wherein matters of importance to electrical engineers can be discussed was felt on all sides. Accordingly the formation of the Electrical Engineering Society was decided upon and the following elected office-bearers for the year :—

Prof. A. Viswanath, B. E., M. SC. (Lond.,)	Patron.
Mr. K. S. B. Easwaran, B. SC. (Hons.,) A. M. I. E.,	President.
Mr. R. G. Janakiram, B. E.,	Treasurer.
Mr. T. Somasundaram, B. A.,	Secretary.
Mr. T. Ramachandran, B. SC.,	4th year representative.
Mr. J. Balaprabudoss.,	3rd year representative.

With message of good wishes received from Dr. J. J. Rudra, Principal, College of Mechanical and Electrical Engineering, Patna (First Principal of the Arthur Hope College of Technology), Lt.-Col. S. Paul, Principal, College of Engineering, Guindy, Mr. K. C. Chakko, Principal, College of Engineering Annamalai University and Rev. Fr. Jerome D'souza, Principal Loyola College and member, Constituent Assembly of India, the society was inaugurated by Major Toshar, R. I. E., B. E., A. M. I. E., A. M. I. Strut. E., wherein he mentioned the scopes for electrical engineers in the army.

Officer Jackson, Officer-in-charge, Peelamedu Civil Aerodrome, spoke to the members on "From an aviator to a lay man".

Sri S. Kandaswamy Mudaliar, Superintending Engineer, Pykara Electric System, addressed the members on "Hydro-electric generation and distribution in South India". He also explained the new proposals on hand for the extension of electricity in South India.

Prof. R. C. Advani, B. SC., A. M. C. T. (Manch.) read a paper on "Industrial Development" with special reference to engineers, capital and employees. Mr. T. Somasundaram read a paper on "Tropical Countries and

Electrical Engineering", Mr. T. Ramachandran read a paper on "Development of modern rotating Electromagnetic machines. Mr. S. Sundaram contributed a paper on "Twenty-four hours of Daylight" a topic on flourescent lighting.

Apart from these, the president delivered several lectures on Radio Engineering which were indeed of great value.

The Valedictory address of the society was delivered by Mr. K. Sreenivasan, M. SC. (Tech). The function was well attended by prominent engineers from the city and others. Mr. Sreenivasan's address on "how and why to advise students" was greatly applauded for its humour, simplicity and sincerity.

With such a start it is hoped that the Society will go from strength to strength.

T. SOMASUNDARAM,
Secretary.

4. STAFF

In the place of Professor K. N. Ramanathan, who was transferred to Cocanada, Professor R. C. Advani, B. SC., B. SC., (Tech). (Man), ; A. M. C. T., took charge as Professor of Electrical Engineering.

We welcome this year Messrs. T. N. Bhima Rao, M. A., L. T., C. Soundraraj, B. SC., B. E., U. S. Chandramauleeswaran, B. E., R. Marudachalam, B. E., and Messrs. M. Barghavan, B. SC. (Hons.), Raghavendra Rao, B. SC. (Hons.) and V. D. Muthia, M. SC.

Mr. A. P. Jambulingam, B. E., Senior Workshop Instructor left early this year for Michigan University, U. S. A. to specialize in Automotive Engineering. Messrs. K. Balakrishnan B. E., and S. Doraiswamy were transferred from the College to P. W. D. Mr. K. Venkataraman was transferred to Anantapur Engineering College.

Our congratulations are due to Mr. M. K. Ganesan, B. E., who has been promoted as Senior Workshop Instructor and Mr. A. Chandrasekharan, B. E., who has been promoted as Assistant Engineer in the P. W. D.

5. LIBRARY

700 books have been added during this academic year. The total number of volumes to-date is 2,700. There are 53 periodicals and magazines got for the benefit of the students.

It is hoped that there will be greater progress in its expansion in future.

6. COLLEGE DAY AND EXHIBITION

The College Day this year was celebrated on a very grand scale on the 25th February, 1949.

The Annual Sports for the year were conducted on the 20th preceding.

On the College Day, an exhibition of all the laboratories and Survey Stores was arranged by the Instructors-in-charge, assisted by the students. There were 1,500 visitors within the short interval of 3 hours during which it was kept open.

It was greatly fitting on the occasion that the founder of the College, Mr. G. D. Naidu presided over the Day's proceedings. Prof. A. Viswanath, the Principal, presented a report of the work done in the year.

Mrs. K. Srinivasan distributed the prizes to the winners in the various sports and games.

There was a variety entertainment at the end, staged by the students, with which the function came to an end.

HOSTEL

1. Cosmopolitan Society:

The Society functioned with the usual vigour. The chief feature of the year was that language sections were introduced separately under the main body.

Mr. M. I. Alee, IV B. E., (Civil) was the Secretary.

2. The Whizz:

There were, besides the usual ones, two outstanding issues. The standard of the magazine has definitely improved under its new Editor, Mr. A. Balakrishnan II B. E.

TOURS

1. IV Year Civils:

We started our series of tours this year early in September, 1948 with a trip to Shervani Hills. There we inspected the headworks provided for the water supply of Coimbatore City.

About a fortnight later we left for Cochin. We stayed there for three days, in which short time, we could see the Harbour, including the docks and the future extension under construction, and the Fertilizers and Chemicals Factory at Alwaye. We spent a day in seeing the dredgers in operation and studying marine surveying.

The next tour was to Madras. There the important places we visited were the Poondi Headworks and the Research Station, Redhills intake tower and prefilters, Kilpauk, water purification and supply works, Napier Park sewage disposal works, the Soil Mechanics Lab. and the Concrete Lab. at Chepauk, and a few other constructions like the Gandhinagar colonisation scheme, Alagappa Chettiar College of Technology, General Hospital Nurses' Home and the construction of the Crompton Engineering Co., at Tiruvottiyur.

The last tour was to Tanjore in January '49. The three days' tour comprised of visits to the cross-drainage works across the Grand Anicut Canal, the Grand Anicut diversion works, the water-supply works of Tanjore town and the Sewage treatment works at Golden Rock. On the way back we spent a few hours in the Erode water purification works which is the only one of its kind in South India.

Project: We did really good work in conducting the preliminary investigation work for the Arakkankottai channel extension scheme which forms one of the minor irrigation schemes of the Madras P. W. D. The two weeks spent there were quite useful for us as well as for the department. A copy of the report with the necessary drawings has been submitted to the P. W. D.

It now remains for me to thank all those who have been responsible for the success of all the tours and the Project-course.

N. V. SHASTRI, B. A.,
Class representative,
Final B. E. (Civil).

2. IV B. E. Electricals:

The Final B. E (Electrical) students during the academic year 1948—'49 had ample opportunities of witnessing places and works of engineering interest in and around Coimbatore.

In October, 1948 we went on an extensive tour of Mysore State. In Mysore we had the unique opportunity of witnessing the Dasara Festivities in full, the Krishnaraja Sagar Dam, the Sandalwood Factory, the Mysore State Railway Workshops etc. At Badhravati, we visited the Iron and Steel Works, the Mysore Paper Mills and Convertor station.

Another interesting feature of the tour was a visit to the Mahatma Gandhi Hydro Electric Works, where power is developed by harnessing the waters of the Sharavati at the Gerosoppa Falls. The Power Station with the transformer yard is well-laid out and the final stages of the work are in progress.

At Bangalore the work we visited were the Kirloskar Motors Ltd. The Indian Institute of Science, The Hindustan Aircraft Factory, and the Kolar Gold Field surface works and mines.

In addition to all these we had a number of local visits in Coimbatore which include the Receiving Station, Stanes Coffee Works, Madukkarai Cement Factory, Ramakrishna Industrials.

T. RAMACHANDRAN, B. SC.,
Class representative,
IV B. E. (Electrical).

3. III B. E. Civils:

During this academic year, we the students of third B. E. Civil class had three major tours and one local inspection.

The only local inspection for this year was to Madukkarai Cement Factory. The students who visited the factory were taken round the various sections so as to get a clear idea of the different processes in the manufacture of Cement.

During the X-mas. vacation we visited the G. A. Canal at Tanjore. We went along the Canal bank for about ten miles and studied the working of the various masonry works on the canal. The next day on our way to Tiruchi we visited the Grand Anicut. At Tiruchi we studied the various principles of interlocking and signalling, in the model room of the South Indian Railway. In addition, we visited the Station yards, Goods yards at Tiruchi Junction and S. I. R. Workshop at Golden Rock.

From the 4th to the 24th of January, 1949 we had Survey camp at Wellington. During this time, we stayed in Army Y. M. C. A. Buildings.

After the camp, we visited the Glenmorgan forebay, went down the winch, visited the Pykara Power House and the Moyar and Pykara Dam Constructions.

M. RADHAKRISHNAN,
Class Representative,
III B. E. Civils.

4. III B. E. Electricals:

The "foreign" trips this year were to Mettur and Pykara. In the first term we went to Mettur, the twenty-seven of us, jollying all the way. At Mettur we were kindly invited to stay at the Mettur Chemicals Hostel. We visited the

Mettur Dam, Power House and Mettur Chemicals. Being the first tour, a study of the "jolly twenty-seven" would indeed have been very interesting. Trekking miles and miles, but still enthusiastic and cheerful! That's what we were.

Having enjoyed this first tour we looked forward very eagerly to the visit to Pykara. It came in January. All fears of biting cold were simply dispensed with and almost all of us were quite pleasant over the trip. We enjoyed very thrilling experiences going down 3,000 feet by winch—an experience unique for many of us. We visited the Singara Power House, Glenmorgan Bay etc. On our way back we halted at Wellington to visit our 'pals' the III B. E. Civils! Oh, What a welcome we got? And what exchange of affections! Well, that was that.

Apart from these we visited Madhukkarai Cement Factory, Ranga Vilas Mills, and Radakrishna Mills.

My thanks are hereby extended to all the authorities concerned who were kind enough in taking us sound.

S. SUNDARAM,
Representative,
III B. E. Electricals.

5. II B. E.

We visited the Madukkarai Cement Factory in October, 1948. Some of us earlier had been on a picnic to the Shervani Hills.

We had our survey camp at Peelamedu in January, 1949 for a fortnight.

A. BALAKRISHNAN,
Class representative,
II B. E. Class.

ATHLETIC CLUB ACTIVITIES.

Our stay in the present premises is very much doubtful and hence we could not make any permanent and desirable changes to our play-fields. With little and insufficient finances due to a small student-body, we were able to meet only the bare necessities.

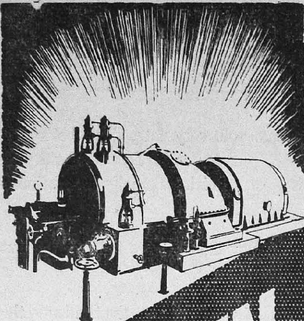
There is a sign of improvement as regards our standards of ability in games as shown by the results in the Madras University Tournaments. We once again won the Coimbatore Divisional Championship in Cricket. But we could not proceed to

Madras for Inter-Division Matches, as they came off very late, just before the University Examinations. Unlike last year, our teams in Tennis singles and Hockey came up for Division finals this year, which is really a creditable achievement.

Intramural Tournaments and the College Day Sports were held for the first time and the Championship cup was won by the III B. E. Class.

In short, with the hearty co-operation of the Staff and the Students, the Activities of the Athletic Club were a great success.

M. RAMA MOHAN RAO,
Secretary,
Aethletic Club and Physical Director.



An Announcement.

★

The TECH-MAG is expected to be a Bi-Annual from next year. With the co-operation that we solicit and surely expect of engineering-minded public, we hope it will function more successfully than ever.

*

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*

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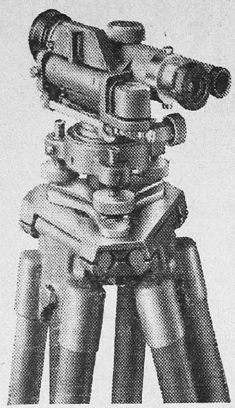
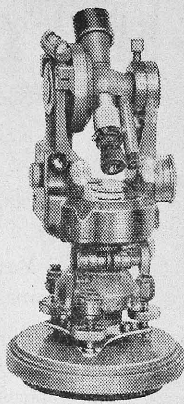
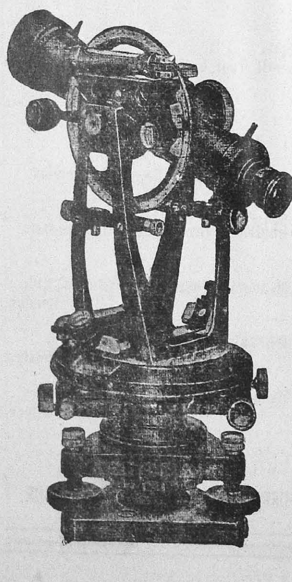
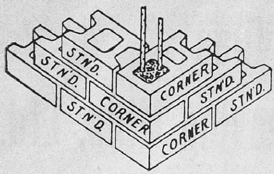


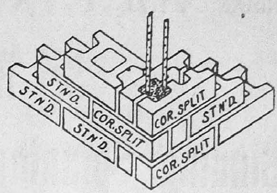




THE MODERN BUILDING MATERIALS

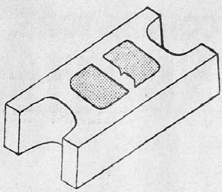


Typical Corner



Corner showing use of NO 8 split corner.

ELECTRICALLY VIBRATED CEMENT CONCRETE 'HOLLO-BLOCKS'



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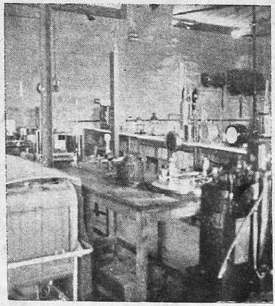

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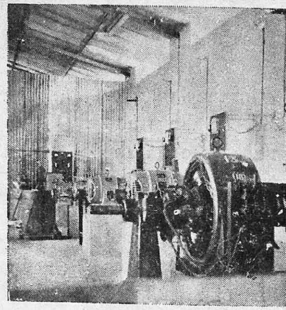
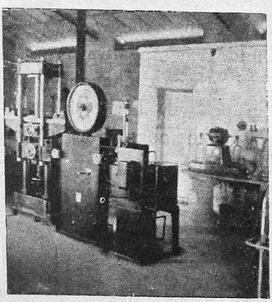


...Electrical Lab



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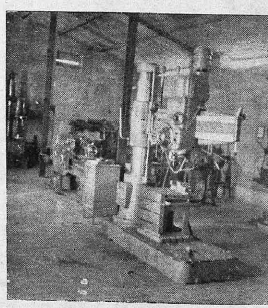

...Workshop

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