2.4 DESIGN PROCEDURES -FLEXIBLE PAVEMENT

For flexible pavements, structural design is mainly concerned with determining appropriate layer thickness and composition. The main design factors are stresses due to traffic load and temperature variations. Two methods of flexible pavement structural design are common today: Empirical design and mechanistic empirical design.

Empirical design

An empirical approach is one which is based on the results of experimentation or experience. Some of them are either based on physical properties or strength parameters of soil subgrade. An empirical approach is one which is based on the results of experimentation or experience. An empirical analysis of flexible pavement design can be done with or without a soil strength test. An example of design without soil strength test is by using HRB soil classification system, in which soils are grouped from A-1 to A-7 and a group index is added to differentiate soils within each group. Example with soil strength test uses McLeod, Stabilometer, California Bearing Ratio (CBR) test. CBR test is widely known and will be discussed.

Mechanistic-Empirical Design

Empirical-Mechanistic method of design is based on the mechanics of materials that relates input, such as wheel load, to an output or pavement response. In pavement design, the responses are the stresses, strains, and deflections within a pavement structure and the physical causes are the loads and material properties of the pavement structure. The relationship between these phenomena and their physical causes are typically described using some mathematical models. Along with this mechanistic approach, empirical elements are used when defining what value of the calculated stresses, strains, and deflections result in pavement failure. The relationship between physical phenomena and pavement failure is described by empirically derived equations that compute the number of loading cycles to failure.

Stresses In Flexible Pavement

Stresses are the response of loading on the pavement. Material containing subgrade and environment condition are also responsible for stresses in the pavement. There are various types of stresses yields in flexible and rigid pavements under the applied live load.

The top most paved surface of such type of pavement is flexible, that is extremely dependent on the underlying layers. Due to flexible, pavement is free to move. In such type of pavements following stresses are the most common and are extremely effective.

- Vertical stresses
- Shear stress
- Radial stress

Vertical stress effects the pavement by compressing the pavement material. When pavement compresses, then material in a pavement gets crushed and as a result rutting become visible on the top horizontal pavement.

Rutting is the depression in the surface of wheel path. Along the sides of the rutting, pavement may uplift (due to shear). These ruts are very clear in the pavement after rain when ruts filled up with water.

Shear stress occurs in the pavement when load is more than the capacity of the pavement. When load approaches the critical point, then as a result movement occurs in the base layer and that movement is responsible for the shear stress in the top pavement.

When tension occurs at the bottom of layers due to seepage, removal of material from particular layer or by any other mean. As a result fatigue cracking occurs in the pavement due to wear and tear of loads. That cracking leads to radial stresses in the pavement

Distribution of stresses in flexible pavement

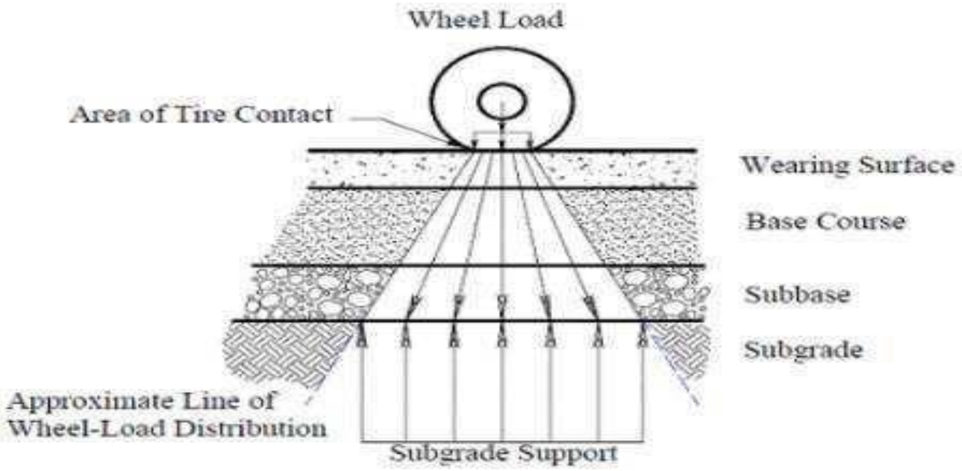


Fig: Distribution of stresses in flexible pavement

Boussinesque's theory

Soils that effect of external load are subjected to stress. The vertical stress increase in soil due to various type of loading. At any point in soil the stress applied from own weight of soil which called effective stress, and from external load which called net stress, the net stress which applied must be determined.

The stress on element:

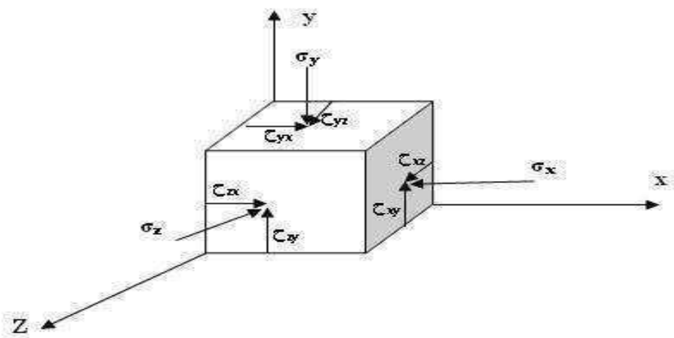


Fig (1): Stresses on element

As shown in fig. 1the stress on element are as follow:

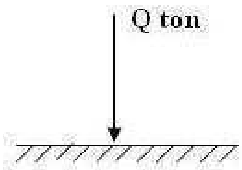
On plan XY the stress are σz,τzx ,τ zy

YZ the stress are σx, τxy, τxz

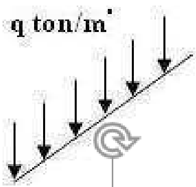
ZX the stress are σy, τyz, τyx

From this σz, σx, σy its stresses called normal stresses, but the other is called shear stresses whichis τxy, τyx, τzy, τyz, τxz, τzx.

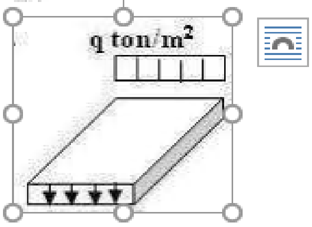
Shape of external load:

1. 

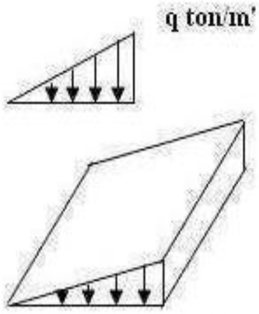
Point load on concentrated load applied from column, wheel of machine, load called point load, because it is effect in point.

2. 

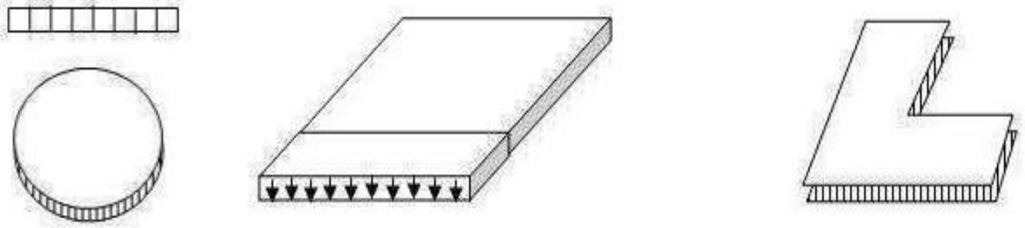
Line load which the load is effect on line as the load on Rail way and Dimension ton/m'.

3. 

Uniform load which the load effect on area, whereas the load uniform and dimension ton/m2

4 . 

Triangular load which applied from embankment, so from the dam, the load dimension is ton/m'

5. 

The loads mention before are uniform load, but the area which load is effect is changed two of themare regular as circular and strip but the other is irregular area although the load is uniform.

Polar coordinate system:

As we know the Cartesian coordinate system which shown in fig. (2) any point (A) in this system defined as three dimension x, y, z.

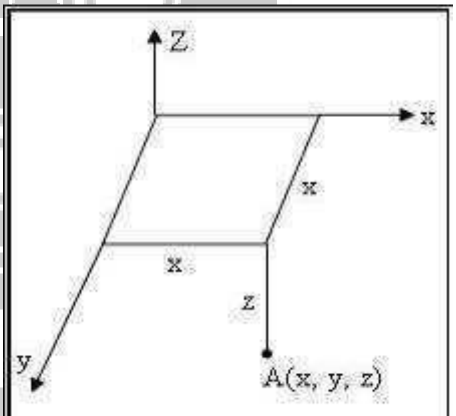


Fig. (2) Cartizian Coordinate

In polar coordinate system point in this system defined as (r, φ,)) as shown in fig. (3).

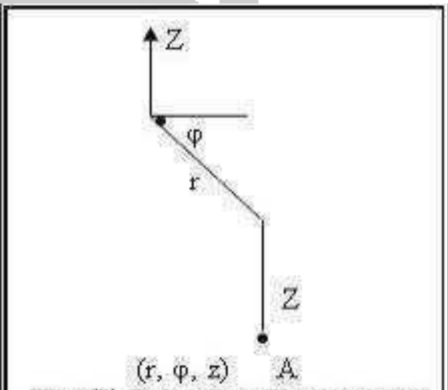


Fig. (3) Polar Coordinate system

The relation between polar and Cartesian coordinate as shown in fig. (4).

$$r = \sqrt{x^2 + y^2}$$

$$R = \sqrt{r^2 + z^2} = \sqrt{x^2 + y^2 + z^2}$$

$$\text{Cos } \alpha = \frac{Z}{R}$$

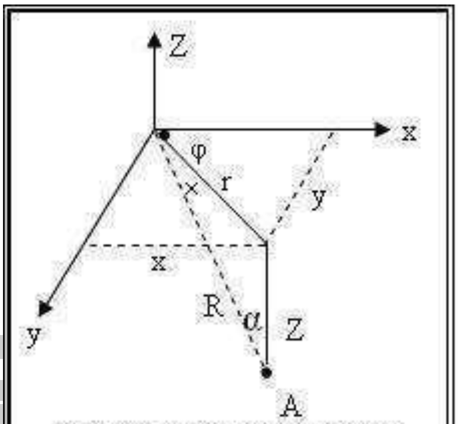


Fig. (4) Polar and Cortizian Coordinate Relation

1) Stress distribution under vertical concentrated load:

Boussinesq's Method:

When a point load Q acting on the surface of a semi infinite solid, a vertical stress σz produces at anypoint in addition to lateral and shear stress.

Assumptions of Boussinesq theory:

a. For soil, the soil mass is elastic, isotropic, homogeneous and semi-infinite.

b. The soil is weightless.

c. For load, the load is vertical, concentrated acting on the surface.

d. Hook's Low Applied, it is mean that the constant ratio between stress and strain.

Boussinesq's Formula:

Boussinesq's solved the problem of stresses produced at anypoint (A) due to point load Q.

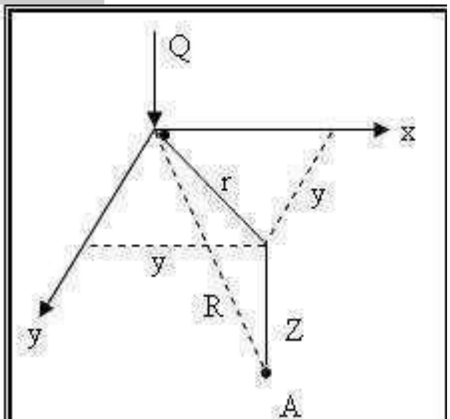


Fig. (5) Point load on the surface

At point (A) …

$$\sigma z = \frac{3Q}{2\pi} \times \frac{Z^3}{R^5}$$

$$\sigma z = \frac{3Q}{2\pi} \times \frac{Z^3 \cdot Z^2}{R^5 \cdot Z^2}$$

$$= \frac{3Q}{2\pi Z^2} \times \frac{Z^5}{R^5} \qquad R^5 = (r^2 + Z^2)^{5/2}$$

$$= \frac{3Q}{2\pi Z^2} \times \frac{1}{\frac{(r^2+z^2)^{\frac{5}{2}}}{Z^2}}$$

$$= \frac{3Q}{2\pi Z^2} \times \frac{1}{(\frac{r^2}{Z^2} + \frac{Z^2}{Z^2})^{\frac{5}{2}}}$$

$$= \frac{3Q}{2\pi Z^2} \times \left[\frac{1}{1+(\frac{r}{Z})^2}\right]^{\frac{5}{2}}$$

$$= \frac{Q}{Z^2}\ \frac{3}{2\pi} \times \left[\frac{1}{1+(\frac{r}{Z})^2}\right]^{\frac{5}{2}}$$

$$\sigma z = \frac{Q}{Z^2} \times I_p \frac{Q}{Z^2} I_p$$

$$\sigma z = \frac{Q}{Z^2} \times I_p \frac{Q}{Z^2} I_p$$

Where:

σz : Vertical stress at point A as shown in fig.(5)

Z : Vertical dimension for point A at load

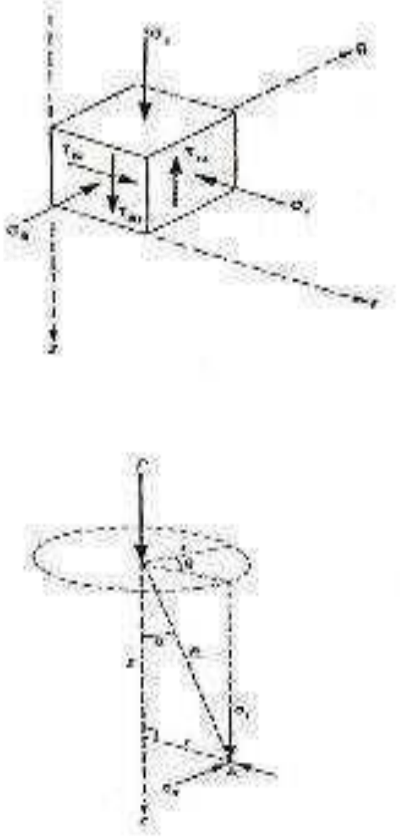
Ip : Influence factor depend on ($\frac{r}{z}$) = F($\frac{r}{z}$)

Q : Point load

The variation of Ip for various value of $\frac{r}{z}$ is given in table (1).

r/z	I_p	r/z	I_p	r/z	I_p	r/z	I_p
0.00	0.4775	0.50	0.2733	1.00	0.0844	1.50	0.0251
0.02	0.4770	0.52	0.2625	1.02	0.0803	1.55	0.0224
0.04	0.4756	0.54	0.2518	1.04	0.0764	1.60	0.0200
0.06	0.4732	0.56	0.2414	1.06	0.0727	1.65	0.0179
0.08	0.4699	0.58	0.2313	1.08	0.0591	1.70	0.0160
0.10	0.4657	0.60	0.2214	1.10	0.0658	1.75	0.0144
0.12	0.4607	0.62	0.2117	1.12	0.0626	1.80	0.0129
0.14	0.4548	0.64	0.2024	1.14	0.0595	1.90	0.0105
0.16	0.4482	0.66	0.1934	1.16	0.0567	2.00	0.0084
0.18	0.4409	0.68	0.1846	1.18	0.0539	2.20	0.0058
0.20	0.4329	0.70	0.1762	1.20	0.0513	2.40	0.0040
0.22	0.4243	0.72	0.1681	1.22	0.0489	2.60	0.0028
0.24	0.4151	0.74	0.1602	1.24	0.0465	2.80	0.0021
0.26	0.4054	0.76	0.1527	1.26	0.0443	3.00	0.0015
0.28	0.3954	0.78	0.1455	1.28	0.0422	3.20	0.0011
0.30	0.3849	0.80	0.1386	1.30	0.0402	3.40	0.0009
0.32	0.3742	0.82	0.1320	1.32	0.0383	3.60	0.0007
0.34	0.3632	0.84	0.1257	1.34	0.0365	3.80	0.0005
0.36	0.3521	0.86	0.1196	1.36	0.0348	4.00	0.0004
0.38	0.3408	0.88	0.1138	1.38	0.0332	4.50	0.0002
0.40	0.3295	0.90	0.1083	1.40	0.0317	5.00	0.00014
0.42	0.3181	0.92	0.1031	1.42	0.0302	6.00	0.00006
0.44	0.3068	0.94	0.0981	1.44	0.0288	7.00	0.00003
0.46	0.2955	0.96	0.0933	1.46	0.0275	8.00	0.00001
0.48	0.2843	0.98	0.0887	1.48	0.0263	10.00	0.00000

$$\sigma_z = \frac{P}{z^2} I_p \qquad \tau_{rz} = \frac{P}{z^2} I_p \frac{r}{z}$$



Stresses due to a point load

Influence factors (I_p) for vertical stress due to a point load.