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Research Article

Depth of Significant Consolidation Pressure underlying Highway Embankment

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Abstract

The Consolidation Pressure to be reduced with the depth of subsoil underlying ha highway embankment. The depth of significant stressed zone at which the pressure reduced to 0.2 or 20%. The magnitude of Significant Consolidation Pressure (D) has been obtained for the range of crest width at the top level of the embankment from 5m to 50m and for the range of embankment height from 1m to 12m considering full consolidation pressure (Δσ). Significant stressed zone 20% of full consolidation pressure (Ds,cp) are found as 2-6.2 He for embankment top width 5-50m. These values are too high and separate values of Dsc for 30% consolidation pressure are also evaluated. Significant stressed zone 20% of full consolidation pressure (Ds,cp) are found as 2-6.2 He for embankment top width 5-50m. These values are not too large and practical to use.

Keywords: Consolidation pressure; Highway embankment; Embankment pressure; Significant stressed zone; Stress distribution

Introduction

The construction highway embankments may be needed on soft or very loose natural subsoil extended to a great depth. The assessment for bearing capacity and settlement of subsoil is subjected to the depth of stressed zone extended into the underlying poor subsoil. The significantly stressed depth of subsoil as a multiplication of embankment height was evaluated in [1] for 70% consolidation pressure. As extension of that research significantly stressed depth of subsoil as a multiplication of embankment height was evaluated through current study for full consolidation pressure. In this research, simplified ratios of embankment height to major influence depth or significant stressed zone are determined for different depths and crest widths of embankment.

Reduction of Embankment Pressure

Embankment Pressure at top of subsoil or at embankment bottom level is termed as $q_e = \gamma_e H_e$ which is considered to be distributed as per Figure 1 [2].

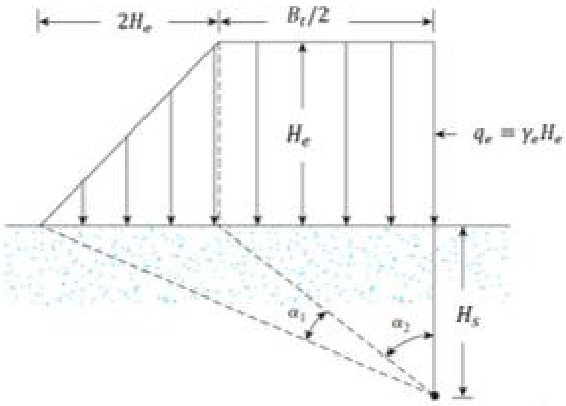

Figure 1: Stress Reduction Due to Embankment loading considering 1V:2H Side slope [3].

Consolidation Pressure at Hs depth of subsoil below center of embankment [3],

$$\Delta\sigma_o = \frac{q_e}{\pi}\left[\left(\frac{\frac{B_t}{2}+2H_e}{2H_e}\right)(\alpha_1+\alpha_2)-\left(\frac{\frac{B_t}{2}}{2H_e}\right)(\alpha_2)\right] \quad (1)$$

where, Hs = Depth of Subsoil underlying embankment, γ_e = Bulk Unit weight of embankment fill, B_t = Width of embankment top.

And in equation (1)

the distance between stressed point and end of embankment top= $\frac{B_t}{2}$

$$\alpha_1 = \tan^{-1}\left(\frac{\frac{B_t}{2}+2H_e}{H_s}\right)-\tan^{-1}\left(\frac{\frac{B_t}{2}}{H_s}\right)$$

$$\alpha_2 = \tan^{-1}\left(\frac{\frac{B_t}{2}}{H_s}\right)$$

and,

$$\alpha_1+\alpha_2 = \tan^{-1}\left(\frac{\frac{B_t}{2}+2H_e}{H_s}\right)$$

Now, for Consolidation Pressure at H_s depth of subsoil below the end of embankment top (replacing $\frac{B_t}{2}$ by 0),

$$\Delta\sigma_1 = \frac{q_e}{\pi}\alpha_1 \quad (2)$$

Considering the distance between stressed point and end of embankment top=0 in equation (2) –

$$\alpha_1 = \tan^{-1}\left(\frac{2H_e}{H_s}\right)$$

and, $\alpha_1+\alpha_2 = \tan^{-1}\left(\frac{2H_e}{H_s}\right) = \alpha_1$

Average Consolidation Pressure at H_s depth below the embankment,

$$\Delta\sigma = \frac{1}{2}\left(\Delta\sigma_0+\Delta\sigma_1\right) \quad (3)$$

where, $\Delta\sigma_0$=Consolidation Pressure at H_s depth below center of embankment and $\Delta\sigma_1$=Consolidation Pressure at H_s depth below edge of embankment top.

In Bangladesh the range of width carriage way is 3.0m to 22.0m [2]. The range of crest width including shoulder, verge and median is 5.0m to 30.0m. For 4 Lane and expressway the range of crest width may be 30m to 40m (Figure 1).

In this study the range of crest width (at top level of embankment) is kept between 5m and 50m. The range of embankment height 1.0m to 12.0m and side slope of embankment 1:2 are taken for analysis.

Depth of Significant Consolidation Pressure

As recommended by [4] the depth of 20% of the foundation contact pressure is significant stressed zone for settlement analysis termed as the significant depth Ds. Terzaghi's suggestion was based on his finding that direct stresses are regarded as negligible if they account for less than 20% of the applied stress.

Consolidation settling of the subsoil underlying the highway embankment will take place for embankment pressure or self-weight produced pressure. Consolidation Pressure (Δσ) is derived from only Embankment Pressure (q_e). The transfer of embankment pressure is significant for assessment of consolidation settlement.

So that, significant stressed zones for Highway Embankment are analyzed accounting full Consolidation Pressure (Δσ) at Hs depth due self-weight induced pressure of embankment.

Now, Consolidation Pressure at Hs depth,

$$\Delta\sigma = \frac{1}{2}\left(\Delta\sigma_0 + \Delta\sigma_1\right) \tag{4}$$

The values of the stress transfer ratio $\Delta\sigma / q_e$ are calculated for different value of H_e, B_e and H_s. Change of $\Delta\sigma / q_e$ for different Depth Ratio $\left(\frac{H_s}{H_e}\right)$ are presented in Chart-1 to Chart-5 for range of B_t =5m to 50m and range of H_e=1m to 12m.

Significant stressed zone for 20% Stress

Depth Ratio $\left(\frac{H_s}{H_e}\right)$ at $\Delta\sigma / q_e = 0.20$ is termed as $\left(\frac{H_s}{H_e}\right)_{0.2}$ for width of Embankment Top, B_t =5m to 50m and height of embankment, H_e=1m to 12m is presented in Table 1 and in Chart-7.

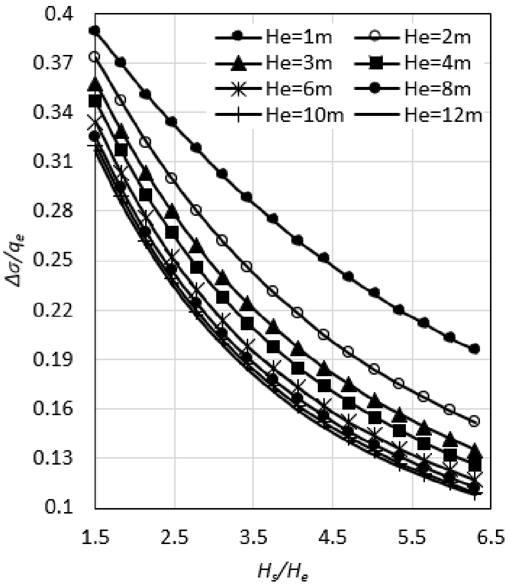

Chart 1: $\frac{H_s}{H_e}$ Vs $\Delta\sigma / q_e$ for Bt=5m.

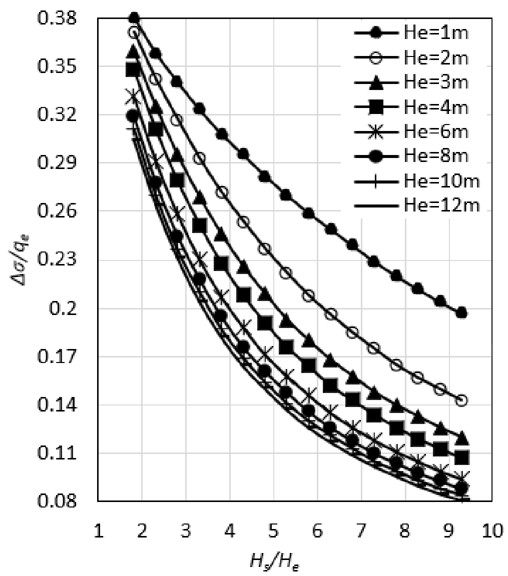

Chart 2: $\frac{H_s}{H_e}$ Vs $\Delta\sigma / q_e$ for Bt =10m.

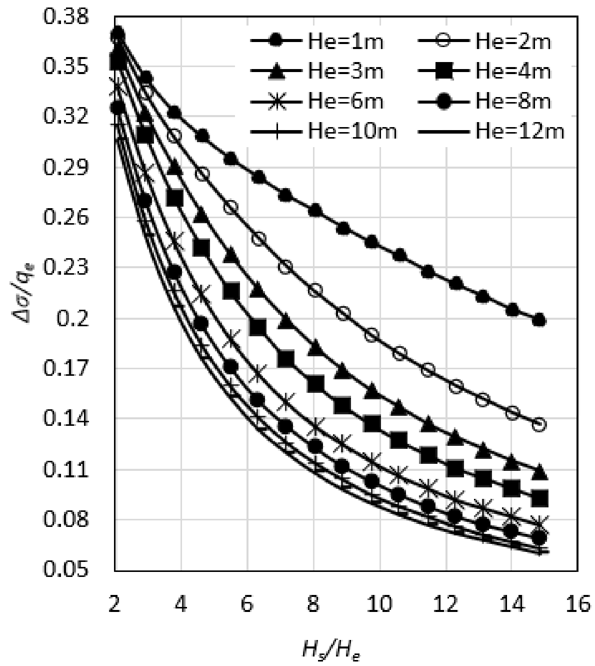

Chart 3: $\frac{H_s}{H_e}$ Vs $\Delta\sigma / q_e$ for B_t =20m.

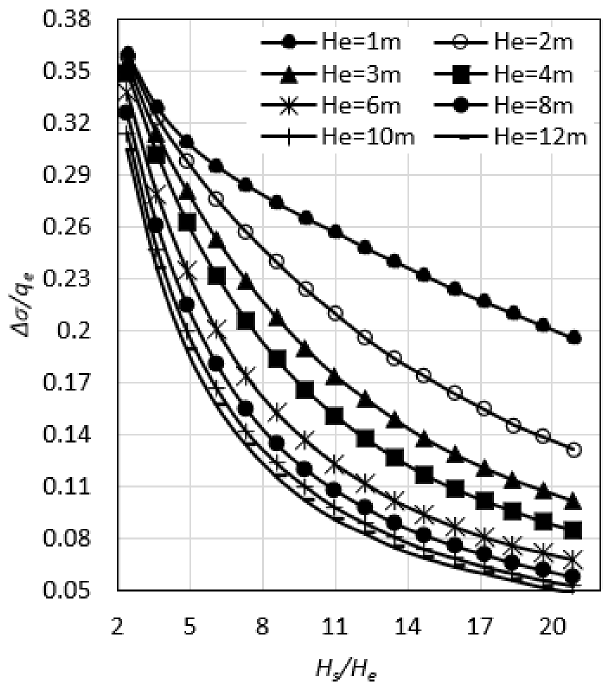

Chart 4: $\frac{H_s}{H_e}$ Vs $\Delta\sigma / q_e$ for B_t =30m.

Depth Ratio $\left(\frac{H_s}{H_e}\right)$ at $\Delta\sigma / q_e = 0.20$ for width of Embankment Top, B_t =5m to 50m and height of embankment, H_e=1m to 12m is presented alternately in Chart-6.

According to power trend line of Chart-6, Depth Ratio $\left(\frac{H_s}{H_e}\right)$ for $\Delta\sigma / q_e = 0.20$ is termed as $\left(\frac{H_s}{H_e}\right)_{0.2}$ may be expressed by equation (5) –

$$\left(\frac{H_s}{H_e}\right)_{0.2} = a\left(H_e\right)^{-b} \quad (5)$$

Significant stressed zone D_s for reduction of 100% consolidation pressure up to 20% is termed as,

$$D_{s,cp,20} = H_e\left(\frac{H_s}{H_e}\right)_{0.2} \quad (6)$$

Hence, the Significant stressed zone, $D_{s,cp}$ may be expressed by equation (7) –

$$D_{s,cp,20} = a\left(H_e\right)^{1-b} \quad (7)$$

Values of coefficient a and b is given in Table 6.

Approximately simplified values of $D_{s,cp,20}$ is given in Table 2 (Table 2).

Table 1: Values of $\left(\frac{H_s}{H_e}\right)_{0.2}$ for width of B_t =5m to 50m and He =1m to 12m.

B_t (m)	5	10	20	30	40	50	H_e (m)
$\left(\frac{H_s}{H_e}\right)_{0.2}$	6.1	9.1	15	20	26	31	1
	4.5	6.1	9.1	12	15	17	2
	4	5.1	7.1	9.1	11	13	3
	3.7	4.5	6.1	7.6	9.1	11	4
	3.4	4	5.1	6.2	7.2	8.2	6
	3.2	3.7	4.6	5.4	6.2	6.9	8
	3.1	3.5	4.2	4.9	5.6	6.2	10
	3.1	3.4	4	4.5	5.1	5.6	12

Table 2: Simplified values of Ds for reduction of consolidation pressure up to 20%.

With of Embankment Top, B_t	5-10	20-30	40-50	H_e (m)
$D_{s\ cp,20}$	9 H_e	20 H_e	30 H_e	1-4
	4 H_e	6 H_e	8 H_e	6-12

Significant stressed zone for 30% Stress

The values of D_s for reduction of consolidation pressure up to 20% is too high. From this thought feasible value of Ds are obtained separately for reduction of consolidation pressure up to 30%.

Depth Ratio $\left(\frac{H_s}{H_e}\right)$ at $\Delta\sigma / q_e = 0.20$ is termed as $\left(\frac{H_s}{H_e}\right)_{0.3}$ for width of Embankment Top, B_t =5m to 50m and height of embankment, H_e=1m to 12m is presented in Table 3 and in Chart-8.

Table 3: Values of $\left(\frac{H_s}{H_e}\right)_{0.3}$ for width of B_t =5m to 50m and He =1m to 12m.

B_t (m)	5	10	20	30	40	50	H_e (m)
$\left(\frac{H_s}{H_e}\right)_{0.2}$	3.15	4.11	5.17	5.65	5.9	6.07	1
	2.46	3.15	4.11	4.76	5.23	5.49	2
	2.18	2.72	3.53	4.13	4.56	4.93	3
	2.02	2.47	3.16	3.69	4.13	4.48	4
	1.86	2.19	2.73	3.18	3.58	3.91	6
	1.76	2.03	2.49	2.88	3.22	3.51	8
	1.71	1.93	2.32	2.66	2.94	3.2	10
	1.67	1.85	2.19	2.47	2.72	2.95	12

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Depth Ratio $\left(\frac{H_s}{H_e}\right)$ at $\Delta\sigma/q_e = 0.20$ for width of Embankment Top, B_t =5m to 50m and height of embankment, H_e=1m to 12m is presented alternately in Chart-9.

According to power trend line of Chart-9, Depth Ratio $\left(\frac{H_s}{H_e}\right)$ for $\Delta\sigma/q_e = 0.20$ is termed as $\left(\frac{H_s}{H_e}\right)_{0.3}$ may be expressed by equation (8) –

$$\left(\frac{H_s}{H_e}\right)_{0.3} = a\left(H_e\right)^{-b} \quad (8)$$

Significant stressed zone D_s for reduction of 100% consolidation pressure up to 20% is termed as,

$$D_{s,cp,20} = H_e\left(\frac{H_s}{H_e}\right)_{0.3} \quad (9)$$

Hence, the Significant stressed zone, $D_{s,cp}$ may be expressed by equation (13.1) to (13.6) –

$$D_{s,cp,30} = a\left(H_e\right)^{1-b} \quad (10)$$

Values of coefficient a and b is given in Table 4.

Approximately simplified values of D_s is given in Table 5.

Table 4: Values of coefficient a and b.

$\frac{H_s}{H_e}$	D_s	Ranges of B_t (m)	a	b	Lowest R^2
$\left(\frac{H_s}{H_e}\right)_{0.2}$	$D_{s\ cp,20}$	5	5.63	0.27	
		10	8.25	0.39	
		20	13.3	0.51	
		30	18.3	0.59	
		40	23.5	0.64	
		50	28.1	0.68	0.9494
$\left(\frac{H_s}{H_e}\right)_{0.3}$	$D_{s,cp,30}$	5	2.98	0.25	
		10	3.96	0.32	
		20	5.18	0.35	
		30	5.86	0.34	
		40	6.28	0.32	
		50	6.53	0.3	0.9705

Table 5: Simplified values of Ds for reduction of consolidation pressure up to 20%.

With of Embankment Top, B_t	5-10	20-30	40-50	H_e (m)
$D_{s,cp,30}$	4 H_e	5.5 H_e	6 H_e	1-4
	2 H_e	3 H_e	4 H_e	6-12

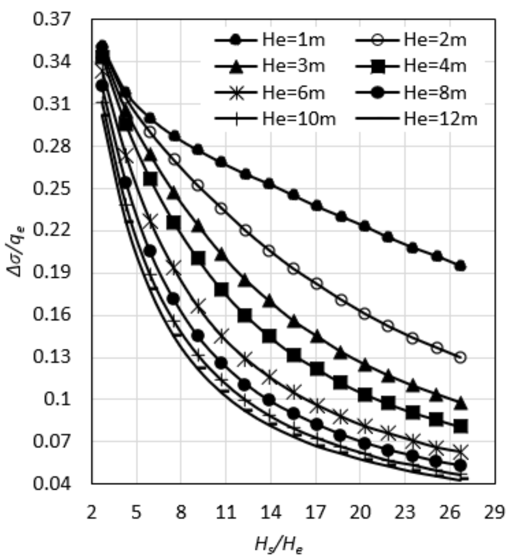

Chart 5: $\frac{H_s}{H_e}$ Vs $\Delta\sigma/q_e$ for B_t =40m.

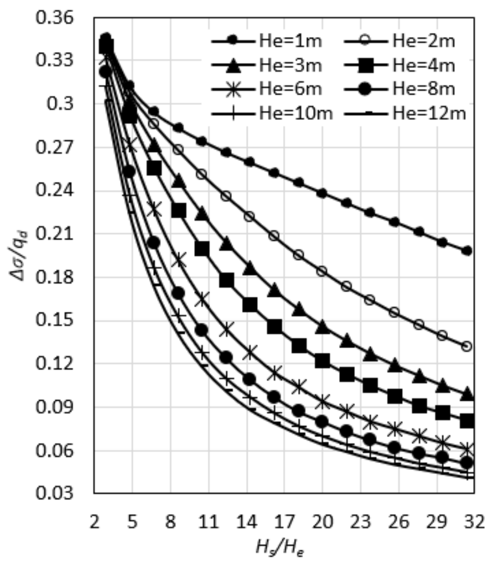

Chart 6: $\frac{H_s}{H_e}$ Vs $\Delta\sigma / q_e$ for B_t =50m.

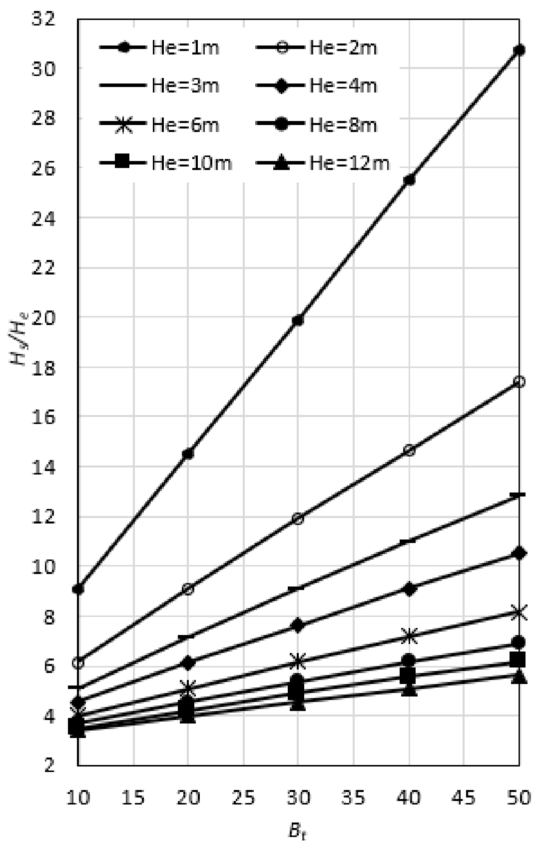

Chart 7: $\frac{H_s}{H_e}$ Vs B_t for $\Delta\sigma / q_e$ = 0.20.

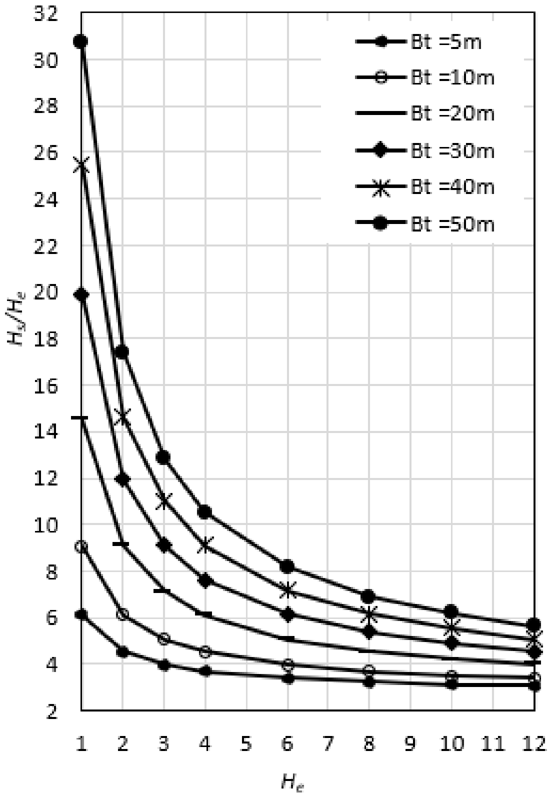

Chart 8: $\frac{H_s}{H_e}$ Vs H_e for $\Delta\sigma / q_e = 0.20$.

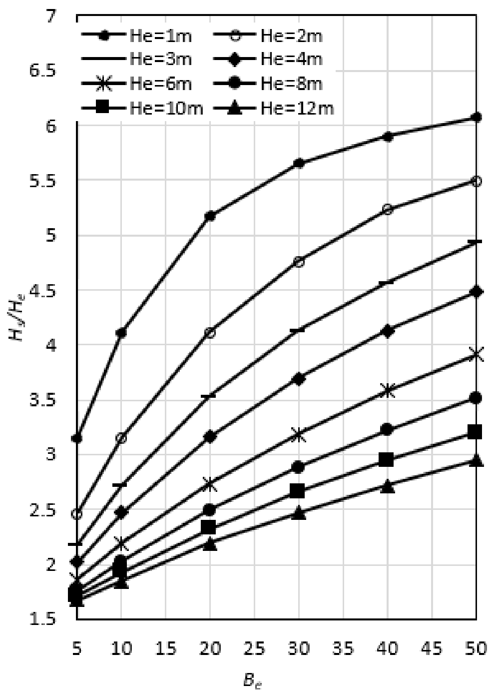

Chart 9: $\frac{H_s}{H_e}$ Vs B_t for $\Delta\sigma / q_e = 0.30$.

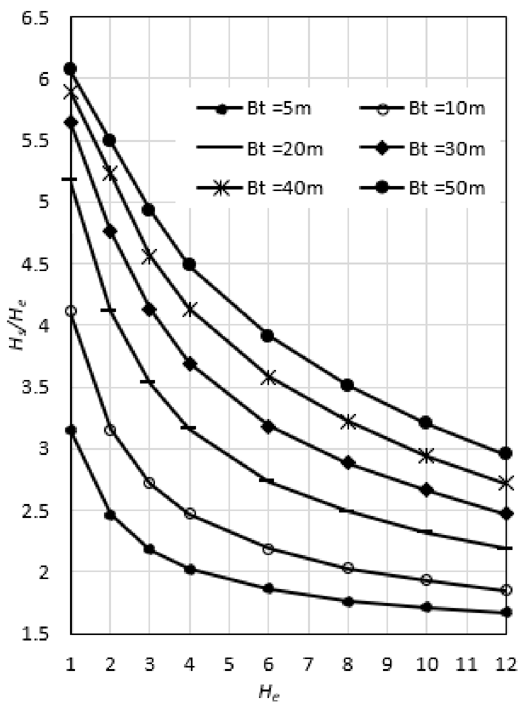

Chart 10: $\frac{H_s}{H_e}$ Vs H_e for $\Delta\sigma / q_e = 0.30$.

Conclusion

The depth of subsoil underlying a highway embankment is identified at which the consolidation pressure is reduced to 20%. This depth is significant stressed zone for $\Delta\sigma / q_e = 0.20$ and termed as $D_{s,cp,20}$. Values of $D_{s,cp,20}$ are found 4H_e to 9H_e for embankment top width 5-10m, 6H_e to 20H_e for embankment top width 20-30m and 8H_e to 30H_e for embankment top width 40-50m. These values are too high and indicates influence of highway embankment up to 70-80m for 30m wide embankment. Considering 70-80m of soft or very loose soil in design not to be feasible. Alternately, the depth is also identified at which the consolidation pressure is reduced to 30%. This depth is significant stressed zone for $\Delta\sigma / q_e = 0.30$ and termed as $D_{s,cp,30}$. Values of $D_{s,cp,30}$ are found 2H_e to 4H_e for embankment top width 5-10m, 3H_e to 5.5H_e for embankment top width 20-30m and 6H_e to 4H_e for embankment top width 40-50m. . These values are not too high and indicates influence of highway embankment up to 20-35m for 30m wide embankment. Considering 20-35m of soft or very loose soil in design may be practically feasible.

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Competing Interest

The author declares that they have no conflict of interest.

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