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RESEARCH ARTICLE

ANALYSIS OF EARTH RETENTION SYSTEM OF CUT AND COVER METHOD FOR TUNNEL CONSTRUCTION.

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Abstract

A tunnel is an underground passageway used for foot or vehicular road traffic, for rail traffic, or for a canal. Earth Retention System i.e. the side concrete wall of cut and cover method for tunnel construction is studied here. The research work is conducted to compare the internal force of side wall computed by conventional method and 3-D computer model result. To achieve the objective, 3-D computer modeling of the whole system, subsequent analysis and result interpretation was performed using the software STAAD Pro. To check the quality of the computer results it is compared with the conventional analysis method inspired by Peck. Finally from the comparison of computer aided assessment and manual calculation, it is revealed that conventional calculation is in good agreement with computer aided assessment. Computer aided assessment should be adapted for detail analysis to get deflection, variation of bending moment on different strip etc. However their suitability varies depending on individual case and some perimeter like time, budget etc.

Introduction:-

A tunnel is an underground passageway, dug through the surrounding soil / earth / rock and enclosed except for entrance and exit, commonly at each end. Shallow-depth tunnels, such as large sewer tunnels, vehicular tunnels, and rapid transit tunnels, are frequently designed as structures to be constructed using the cut and cover method (Wilton, J. L. 1996). Tunnel construction is characterized as "cut and cover" construction when the tunnel structure is constructed in a braced, trench type excavation ("cut") and is subsequently backfilled ("covered") (Bickel et al, 1997).

Cut-and-cover is a simple method of construction for shallow tunnels where a trench is excavated and roofed over with an overhead support system strong enough to carry the load of what is to be built above the tunnel (Ellis, Iain W, 2015). In a cut and cover tunnel, the structure is built inside an excavation and covered over with backfill material when construction of the structure is complete. Two types of construction are employed to build cut and cover tunnels; bottom-up and top-down.

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Literature Review:-
The "Cut and Cover" method has been used for a long time in urban subway construction but also in interurban transportation projects, in the construction of relatively short and shallow highway and railway tunnel and the "Cover and Cut" method was originally developed for construction of shallow underground structures where the least possible disruption of traffic is required. (Mouratidis, 2008).

For depths of 30 to 40 feet (about 10 m to 12 m), cut-and-cover is usually more economical and more practical than mined or bored tunneling. The cut-and-cover tunnel is usually designed as a rigid frame box structure. In urban areas, due to the limited available space, the tunnel is usually constructed within a neat excavation line using braced or tied back excavation supporting walls. Wherever construction space permits, in open areas beyond urban development, it may be more economical to employ open cut construction.

Where the tunnel alignment is beneath a city street, the cut-and-cover construction will cause interference with traffic and other urban activities. This disruption can be lessened through the use of decking over the excavation to restore traffic. While most cut-and-cover tunnels have a relatively shallow depth to the invert, depths to 60 feet (18 m) are not uncommon; depths rarely exceed 100 feet (30 m).

However, there could be some temporary considerations to reduce the traffic congestion when an open trench is constructed in urban regions (Pakiman et al., 2015). Overall, it should be noted that in the cut and-cover method, most construction efforts and resources are spent on trench excavation, shoring, dewatering, embedment, backfilling and compacting, and reinstating the surface (Najafi and Gokhale, 2005).

Methodology:-
The Cut and Cover method of tunneling is relatively cheap for shallow tunnels and requires simple technology. The geotechnical study is immensely important as it evaluates the fundamental input for the static calculation of the tunnel. Subjected to the soil pressure, a reinforced concrete structure deforms activating its structural strength. The consecutive displacements in the surrounding soil induce stress redistributions. This generally leads to a more favorable situation for the structure, which is usually recognized simply by assuming an active stress state in the soil.

Soil Profile:-
For this study the considered soil profile is collected from a research work of Waheed (2008). According to his thesis paper a table of different cases based on soil type are presented in Table 1.

Table 1:-Different cases based on soil type for design of earth retention

Case	Soil class	Layer depth (ft)	Cu(psf) (Typical)	**Ø**(degree)	Reference
Case-1	Clay, C4	20	2400	-	BH : 10
	Sand, S4	30	-	35	
Case-2	Clay, C5	17	3000	-	BH : 25 BH :26
	Clay, C4	60	2400	-	
	Sand, S3	23	-	30	
Case-3	Clay, C2	65	900	-	BH : 12
	Sand, S5	35	-	40	
Case-4	Clay, C2	14	900	-	BH : 8
	Clay, C4	16	2400	-	
	Sand, S3	30	-	30	
	Sand, S4	20	-	35	
	Sand, S5	20	Nil		

In this study Case-1 is selected to compare the result. Case-1 corresponds to 20 ft depth of upper clay layer, which is the minimum clay layer depth encountered along the tunnel alignment. It was found between Kawran-Bazar and Tejgaon industrial area. The clay layer is C4 class with cohesion varying from 2230 psf to 2520 psf. The typical value of 2400 psf has been used in the design. The underlying sand layer is of S4 class with angle of internal friction of about 35°. According to Waheed (2008) the soil parameters presented in Table 2.

Table 2:-Cases-I soil parameter for design of earth retention

Soil type	Depth Variation (ft)	Depth Height (ft)	γ_d lb/ft3	γ_{sat} lb/ft3	γ' lb/ft3	Min^m Cu (psf)	Max^m Cu (psf)	Avg Cu (psf)	Ø (deg)	Ka	Kp
Clay, C4	0-20	20	111.57	138.35	75.95	2232	2520	2376	0	1	1
Sand, S4	20-50	30	111.57	138.35	75.95	0	0	0	35	0.271	3.69

Earth Pressure Calculation by Conventional Method:-

In this study the earth retention system analyzed based on braced-cut method. To evaluate the performance of earth retention system by braced cut, a complete sample design calculation of braced cut with 50 ft depth of excavation has been carried out as shown in Figure 1 and Figure 2. Here initial strut was chosen at a depth of 12.5 ft, other strut were spaced at a distance of 10 ft and thus the last strut is placed at 7.5 ft above the bottom of the cut. Peck (1969) suggested using design pressure envelopes for braced cuts in sand and clay. Based on Peck's suggestion the detail calculation was conducted with the help of design examples demonstrated by Arora (2003) and Das (2004) in their books.

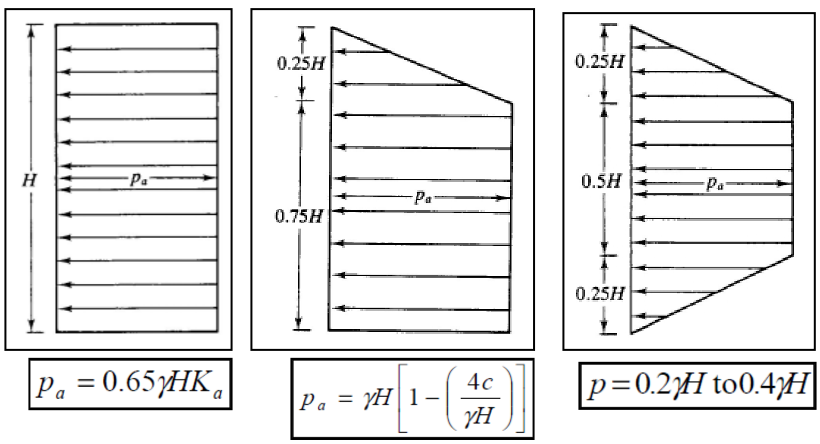


Fig 1:-Peck's (1969) apparent- pressure envelope for cuts

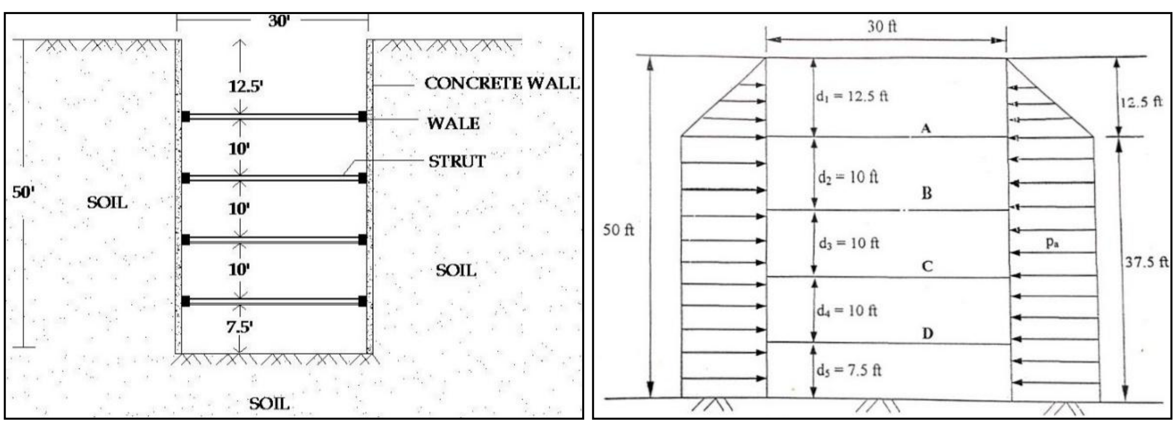
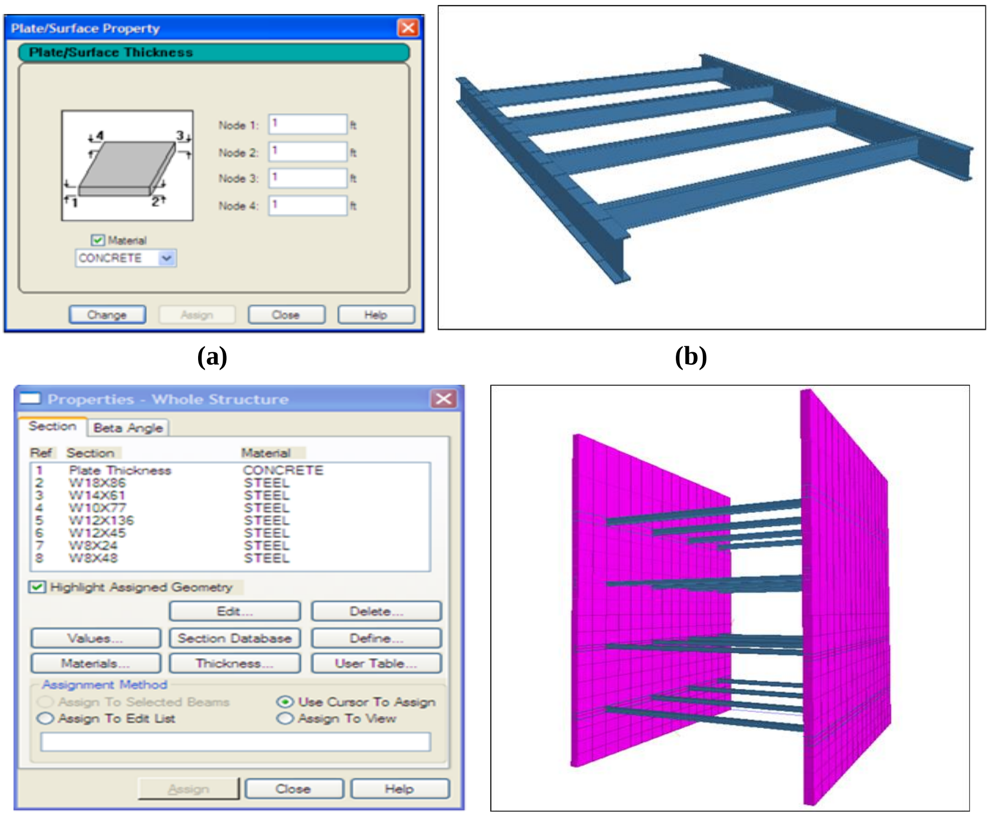


Fig 2:-Pressure distribution diagram in Braced Cut

Numerical Model Development:-

For numerical model STAAD Pro. software is used for this study. At first two side walls of 30 ft apart are developed and meshed the wall at a standard side. Then horizontal steel beam are placed as wales. After placing the wales the struts are assigned at standard distance considering the wall mesh. For strut W12x45, W8x48, W8x24 and for wales W18x86, W14x61, W10x77, W12x136 sections are used considering the stressed developed by retaining soil. Applied fixed support at the base of the wall. The wall properties are Cement concrete (CC) type of 10 inch thickness. The soil load started zero at top of the wall and increased to maximum of 1.867 ksf at 12.5 ft from the top. The load distribution at base plate is even. The 3D model development and load distribution is presented from Fig. 3 and Fig. 4



(c) **(d)**

Fig 3:-3D model development in STAAD Pro., a) properties of side wall, b) 3D view of struts and wales arrangement, c) properties developments for struts and wales and d) 3D view of braced-cut

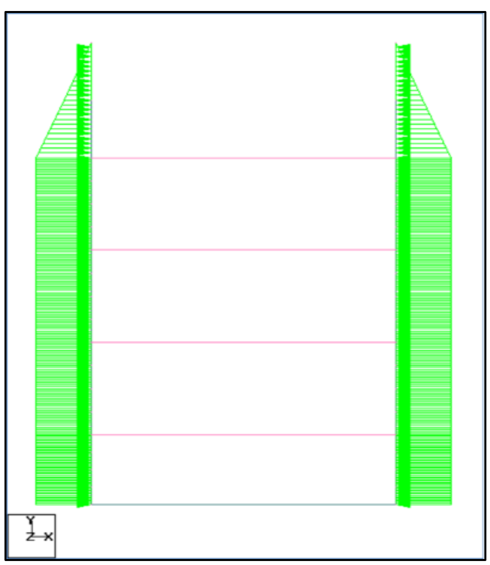


Fig. 4:-Load Distribution on side wall

Result and Discussion:-

From the analysis of Earth Retention system based on conventional method as discussed earlier the reaction of struts are calculated. Using this reaction the Bending Moment diagrams (BMD) are developed as shown in Fig. 5.

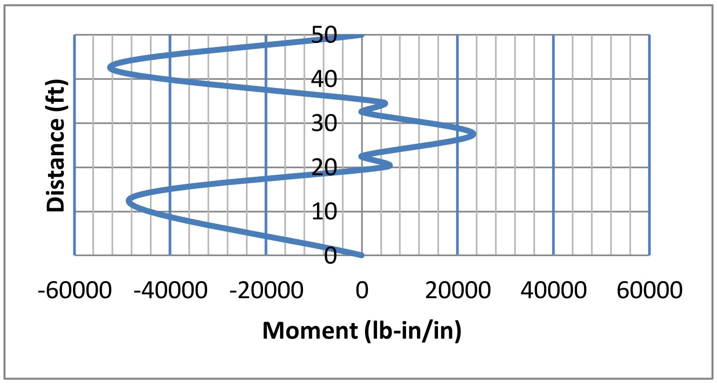


Fig 5:-Vertical moment diagram by conventional method

The vertical moment from STAAD Pro. analysis at critical locations i.e. middle of the side wall, middle bracing and side bracing is considered as shown in Fig.6. and Fig. 7.

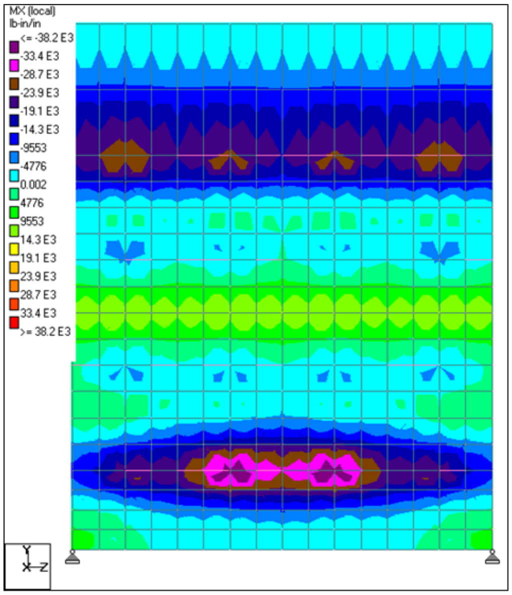
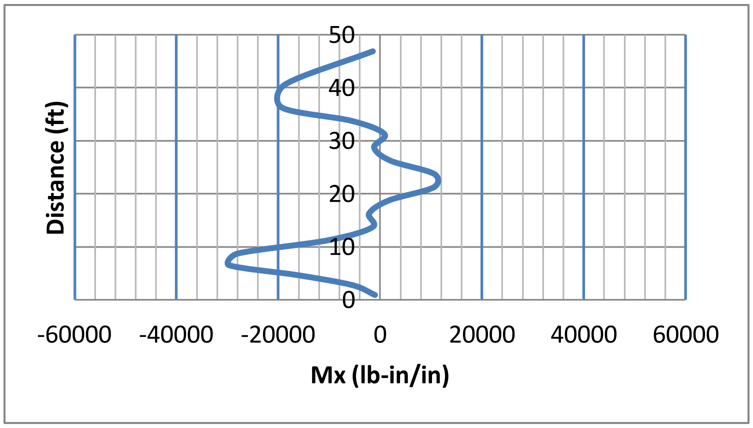
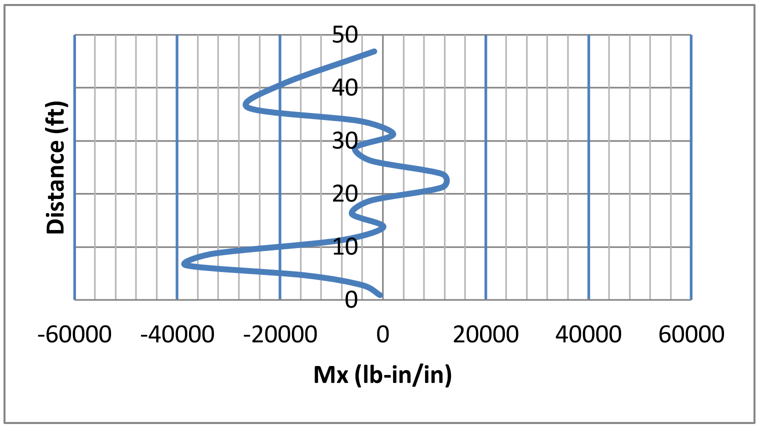


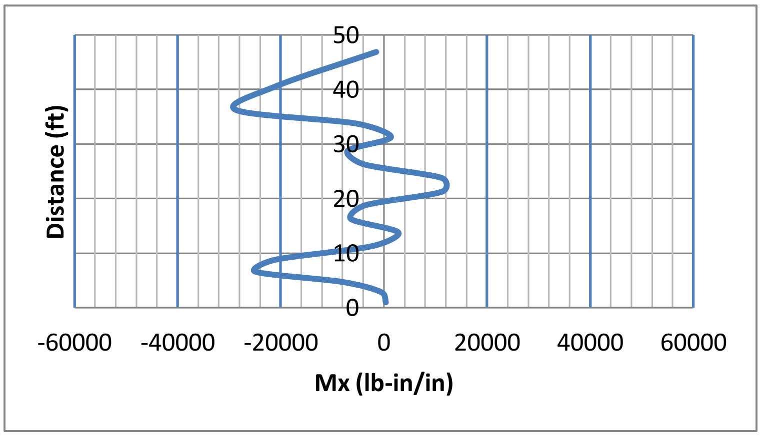
Fig 6:-Vertical moment profile from STAAD Pro. Analysis



(a)



(b)



(c)

Fig 7:-Vertical moment by STAAD.Pro, a) at middle of the side wall, b) at middle bracing and c) at side bracing

The result obtained by conventional method and computer aided assessment shows almost same graphical geometry but the values are different. At 42.5 ft. manual calculation shows negative moment of 4.17 kip-ft. where STAAD Pro gives 2.5 kip-ft. At 27.5 ft. manual calculation gives 1.67 kip-ft. and from STAAD Pro we found it 0.83kip-ft.

This is probably due to the fact that conventional calculation is overly simplified method which ignores the moment transformation through joints and beams. It is also probably due to the fact that conventional calculation does not take in account of the wall thickness and the resistance provided from the beam. It does not consider wales and it also does not recognize the properties of wide flange which is used as strut and wales. The values from STAAD Pro seemed more accurate because it considers the section properties supporting members and wall thickness. So the result from computer aided assessment is so far more acceptable and pleasing.

Table 3:-Maximum Axial force of different bracing

Steel Section	Maximum Axial Force of Bracing	Bracing Position
W12x45	269.15 kip	Bottom Bracing
W12x72	271.17 kip	Bottom Bracing
W12x96	271.79 kip	Bottom Bracing
W12x120	271.97 kip	Bottom Bracing

Conclusion:-

Cut-and-Cover tunneling is a very useful method for shallow tunnels in adverse ground conditions, in both urban and rural areas. Earth retention system analysis is the most vital part of cut and cover method. In this study earth retention system of cut and cover method is analyzed by conventional and computer aided assessment method (STAAD Pro).

Considering the results and discussion it can be conclude that conventional calculation method is in good agreement with computer aided assessment but in terms of accuracy and level of precision computer aided assessment method is best. Manual calculation is not so precise and its accuracy is hampered as it does not recognize the wide flange section properties. For detail analysis computer aided assessment should be adapted.

In terms of complexity Computer aided analysis method is the most complex one. Apart from knowledge of Structural Engineering one needs knowledge about using computer and considerable amount of practice and training of the software. On the other hand the process of conventional analysis method based on empirical formula are fairly simple and easy to understand. Conventional calculation analysis method does not require anything else except for the knowledge of the method.

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