Engineering approach to seismic analysis and design tunnels engineering essay

1) Land shaking ; and 2) land failure such as liquefaction, mistake supplanting, and incline instability. The chief involvement of this survey is ground shaking, which means the distortion of the land developed by seismal moving ridges propagating through the Earth 's crust. The major factors act uponing agitating harm include (1) the form, dimensions and deepness of the construction ; (2) the belongingss of the environing dirt or stone ; (3) the belongingss of the construction ; and (4) the badness of the land shaking (Dowding and Rozen, 1978 ; St. John and Zahrah, 1987.) .

Harmonizing to Hashash et Al. (2001) the rating of belowground construction seismal response requires an apprehension of the anticipated land shaking every bit good as an rating of the response of the land and the construction to such shaking. The seismal response of inhumed constructions can be summarized as following three major stairss:

1) Definition of the seismal environment and development of the seismal parametric quantities for analysis.

2) Evaluation of land response to shaking, which includes land failure and land distortions.

3) Appraisal of construction behaviour due to seismic agitating including ; (a) development of seismal design lading standards, (B) resistance construction response to land distortions, and (degree Celsius) particular seismal design issues.

Seismic design of belowground constructions differs above land constructions in several ways. For most belowground constructions, the inactiveness of the environing dirt is big comparative to the inactiveness of the construction. Measurements made by Okamoto et Al. (1973) of the seismal response of an immersed tubing tunnel during several temblors show that the response of a tunnel is dominated by the environing land response and non the inertial belongingss of the tunnel construction itself. Therefore, the chief point of belowground seismal design is on the free-i¬? eld distortion of the land and its interaction with the construction. The accent on supplanting is wholly contrast to the design of surface constructions, which focuses on inertial effects of the construction itself. This difference force to develop new design methods such as the Seismic Deformation Method that chiefly analyses the seismal distortion of the land.

Historically, there exist simple province attacks for measuring the response of the construction:

Dynamic earth force per unit area (Monobe-Okabe)

Free field distortion attack

It is known that dynamic earth force per unit area method have been suggested for the belowground box constructions and used widely for non merely belowground constructions but besides construction overlying to the land such as retaining walls. This method supplies designer a good estimation for the burden mechanism if the construction is non deep so much and holding rectangular cross subdivision. For a inhumed rectangular structural frame, the land and the construction would travel together, doing it improbable that a giving active cuneus could organize. Therefore, its pertinence in the seismal design of belowground constructions has been the topic of contention (Wang, 1993) .

In the free field distortion attack, the land is subjected to seismic wave extension without being of the construction. This attack ignores the being of the construction and the pit. The estimated distortions occurred at the land is applied to the construction and the response of the construction is estimated. For simpleness, Newmark (1968) and (Kuesel, 1969) suggest a simplified attack which is based on theory of wave extension in homogenous, isotropic, elastic media. The land strains are calculated by presuming a harmonic moving ridge of any moving ridge type propagating at an angle (angle of incidence) with regard to the axis of a planned construction. They represents free-field land distortions along a tunnel axis due to a harmonic moving ridge propagating at a given angle of incidence (Figure 2. 1) . Because of non reasoning the angle of incidence for the prevailing seismal moving ridges faithfully, a conservative premise of utilizing the most critical angle of incidence giving maximal strain is made.

Figure 2. 1) Simple harmonic moving ridge and tunnel (Wang, 1993) .

Where ;

L= wavelength

D= supplanting amplitude

?¤iˆ = angle of incidence

St. John and Zahrah (1987) improved Newmark 's attack to widen solutions for free-i¬? eld axial and curvature strains due to compaction, shear and Rayleigh moving ridges. Solutions for all three wave types are shown in Table 2. 1, though S-waves are typically associated with peak atom accelerations and speeds (Power et al. , 1996) . The seismal moving ridges doing longitudinal and bending strains are shown in Fig. 2. 2. It is frequently difficult to find which type of moving ridge will regulate. Strains produced by Rayleigh moving ridges tend to rule merely in shallow constructions and the seismal beginning distant from the sites (Wang, 1993) .

Table 2. 1)

Where ;

R: radius of round tunnel or half tallness of a rectangular tunnel

? p: peak atom acceleration associated with P-wave

? s: peak atom acceleration associated with S-wave

? R: peak atom acceleration associated with Rayleigh wave

?¤ : angle of incidence of moving ridge with regard to burrow axis

i?®l: Poisson 's ratio of tunnel run alonging stuff

Vp: peak atom speed associated with P-wave

Cp: evident speed of P-wave extension

Volt: peak atom speed associated with S-waves

Cesium: evident speed of S-wave extension

VR: peak atom speed associated with Rayleigh wave

Chromium: evident speed of Rayleigh wave extension

Figure 2. 2) Seismic waves doing longitudinal and bending strains (Power et al. , 1996)

Harmonizing to the method proposed by St. John and Zahrah (1987) minutes and forces generated in tunnel liner are expressed in following equations:

Where M, flexural minute ; V, shear force ; Q, thrust force ; , angle of wave impact ; , minute of inactiveness of tunnel liner ; , modulus of snap of run alonging stuff ; D, amplitude of sine moving ridge ; L, shear wave length ; and ; subdivision country of liner.

In add-on to these simple province attacks, there exist more elaborate design applications that are used in the yesteryear.

Soil-Structure interaction finite element analysis: elastic or inelastic 2-D/3-D analysis carried out in frequence or clip sphere ;

Simplified frame analysis theoretical account: the effects of the soil-structure interaction are simulated utilizing an appropriate set of springs and dampers.

The finite component method is the most popular and executable application used in geotechnical technology up to day of the month. It has been extensively admitted the benefits of the finite component method for the solution of hard state of affairss that had overcame conventional and closed-form methods. For seismal design and analysis of tunnels, it is besides the best solution that can be applied. Although, it consumes little more clip, today 's computing machine engineerings handle with the tally clip procedure with shortening its continuance. In finite component analysis, each of the elements is assigned constituent stuff belongingss. Nearly exact solution can be developed for each component. The entire solution is so produced by piecing the single solution guaranting continuity at the boundaries between the finite elements.

An equal attack may be provided by simplified frame analysis for the design of belowground constructions. The followers is a bit-by-bit process for such an analysis. It has been proposed by Hashash et Al. (2001) , based in portion on the work by Monsees and Merritt, (1988) , and Wang (1993) :

Structure dimensions and the construction members ' sizes are designed based on inactive burden demands.

Estimate the free-field shear strains/deformations of the land based on land response analyses for a vertically propagating shear moving ridge.

Determine the comparative stiffness i. e. the flexibleness ratio between the land and the construction.

Determine the racking coefficient, R based on the flexibleness ratio.

Calculate the existent racking distortion of the construction as ? structure= R? free-field

Enforce the seismically-induced racking distortion in a inactive structural analysis.

Add the racking-induced internal demands to other inactive burden constituents.

If the consequences from 7 show that the construction has equal capacity, the design is considered satisfactory. Otherwise, continue.

The construction should be redesigned if the strength demands are non met, and/or the ensuing inelastic distortions exceed allowable degrees depending on the construction public presentation aims.

Modify the size of structural elements as necessary. Reinforcing steel per centums may necessitate to be adjusted to avoid brickle behaviour. Under inactive or pseudo-static tonss, the maximal useable compressive concrete strain is 0. 004 for flexural and 0. 002 for axial burden.

Table 2. 2 Seismic design attacks for an belowground construction [after Wang, 1993]

Reappraisal on Seismically-Induced Distortions at Tunnel Linings

In this chapter, brief sum-up of distortion manners are presented at tunnel liners under cycling loading conditions. Owen and Scholl, 1981, claimed that the behaviour of a tunnel can be sometimes approximated to that of an elastic beam topic to distortions imposed by the environing land. Three types of distortions represent the response of belowground constructions to seismal gestures: (1) Axial compaction and extension (Fig. 2. 3 a, B) ; (2) Longitudinal bending (Fig. 2. 3 degree Celsius, vitamin D) and (3) Ovaling / racking (Fig. 2. 3 vitamin E, degree Fahrenheit) . Axial distortions in tunnels are created by the constituents of seismal moving ridges that produce gestures parallel to the axis of the tunnel and cause interchanging compaction and tenseness. Bending distortions are caused by the constituents of seismal moving ridges bring forthing atom gestures perpendicular to the longitudinal axis. Design considerations for axial and bending distortions are by and large in the way along the tunnel axis (Wang, 1993) .

Ovaling or single-footing distortions in a tunnel construction develop when shear moving ridges propagate normal or about normal to the tunnel axis, ensuing in a deformation of the cross-sectional form of the tunnel liner. Design considerations for this type of distortion are in the cross way. The general behaviour of the liner may be simulated as a inhumed construction topic to land distortions under a planar plane-strain status.

Figure 2. 3) a) Compression-extension

Figure 2. 3-) B) Compaction of tunnel subdivision

Figure 2. 3) degree Celsius) Longitudinal bending distortion

Figure 2. 3-) vitamin D) Diagonally propagating moving ridge distortions

Figure 2. 3) vitamin E) Ovaling of tunnel subdivision

Figure 2. 3) degree Fahrenheit) Racking of tunnel subdivision

Ovaling and racking of the tunnel are the most important distortion manner for the tunnel subdivisions.

Next, the attacks used for the design of round tunnels are discussed in item.

Seismic Design Approaches Used for Circular Tunnels

In this subdivision, seismal design attacks are described in inside informations: analytical or pseudo-static, and numerical methods.

Ovaling distortion of round tunnels with free-field distortion attack

Ovaling distortions are created by the moving ridges that moving sheer to the tunnel axis. Like single-footing distortions, ovaling distortions are developed in the cross way of the tunnel axis. Vertically propagating shear moving ridges are the prevailing signifier of the temblor burden that causes these types of distortions (Wang, 1993) .

Shear deformations of the land can be defined in two ways, (1) Non-perforated land, and (2) Perforated land (Figure 2. 4) . Plane strain conditions are considered. The maximal diametral strain ? d is a map of the maximal free-field shear strain i?§max in the non-perforated land.

where vitamin D is the diameter of the tunnel.

In the pierced land, the diametral strain is related to the Poisson 's ratio of the medium.

The equations above are disregarding line drive and besides the affect of soil-structure interaction. As expected the perforated land outputs much greater deformation than the non-perforated land. Consequences obtained from the perforated land are acceptable for soft liner. For the liner stiffness equal to that of environing land, non-perforated consequences provide sensible appraisals. A liner with big comparative stiffness should see deformations smaller than those given by Eq. (2. 5) (Wang, 1993) .

Figure 2. 4) Free-field shear deformation of pierced and non-perforated land, round form tunnels (after Wang, 1993) .

Longitudinal distortion of round tunnels with ground-structure interaction attack

In this attack, the presence of the inhumed construction is evaluated. It is supposed that the being of the construction modifies the distortion behaviours of the environing medium. To pattern soil-structure interaction, beam-on-elastic foundation theory is used. Dynamic inertial interaction effects are assumed to be ignored in this solution. Under seismal burden, the cross-section of a tunnel will see axial bending and shear strains due to free field axial, curvature, and shear distortions (Figure 2. 5) . St. John and Zahrah, 1987 suggested that maximal strains are caused by a moving ridge with angle of incidence 450. The ensuing maximal axial strain, ? amax, is formed by a 450 shear moving ridge (Figure 2. 2) is:

Where

Liter: wavelength of an ideal sinusoidal shear moving ridge

Ka: longitudinal spring coefficient of land medium ; in force per unit distortion per unit length of tunnel)

A: free-field supplanting response amplitude of an ideal sinusoidal shear moving ridge

Actinium: cross-sectional country of tunnel liner

Elevation: elastic modulus of the tunnel liner

degree Fahrenheit: ultimate clash force (per unit length) between tunnel and environing dirt

Figure 2. 5) Induced forces and minutes caused by seismal moving ridges (Power et al. , 1996) . (a) Induced forces and minutes caused by moving ridges propagating along tunnel axis, (B) Induced circumferential forces and minutes caused by moving ridges propagating perpendicular to burrow axis.

In equation 2. 6, it is stated that the maximal frictional forces that can be occurred between the liner and the medium restrict the axial strain in the liner. The maximal clash shear is dependent on the raggedness of the ground-tunnel interface and the normal force applied to the tunnel from the land (Hongbin Huo, 2005) . When the incident angle of shear moving ridge is equal to 0 & A ; deg ; , the maximal bending strain occurs (Figure 2. 2) :

Where

Intelligence community: minute of inactiveness of the tunnel subdivision

Karats: transverse spring coefficient of the medium (in force per unit distortion per unit length of tunnel (see Eq. 2. 12) .

R: radius of round tunnel or half tallness of a rectangular tunnel

The maximal shear force on the tunnel cross-section can be written as a map of this maximal bending strain:

The maximal bending minute is:

The maximal axial force is:

A conservative estimation of the entire maximal axial strain is obtained by uniting the axial and bending strains because of presuming the line drive and the surrounding medium are additive elastic (Power et al. , 1996) :

In the equations stated above the response is modeled by utilizing springs with the spring coefficients Ka and Kl for longitudinal and cross dirt subdivision.

Ka and Kl are maps of incident moving ridge length (St. John and Zahrah, 1987) :

where Gm and ? m: shear modulus and Poisson 's ratio of the medium, vitamin D: diameter of round tunnel or tallness of rectangular construction, L: wavelength.

Harmonizing to Wang, the derivations of these springs differ from those for the conventional beam on elastic foundation jobs in that:

-The spring coefficients should be representative of the dynamic modulus of the land under seismal tonss.

-The derivations should see the fact that lading felt by the environing dirt is alternately positive and negative due to the assumed sinusoidal seismal moving ridge.

Some research workers suggested approximative values for the moving ridge length of land gesture:

Where T is the prevailing natural period of the dirt sedimentation, and Cs is the shear moving ridge speed.

Where H is the thickness of the dirt bed.

It will go on.