# Use of secondary reinforcement for connection for block facing reinforced soil wall

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ABSTRACT: Reinforced Soil wall are designed with various facing options such as Segmental panel, full height panel, Gabion, welded wire mesh and block. Facings are selected with the consideration of connection, compatible with and vice versa. There are majorly two type of connections are considered, for Reinforced soil walls, i.e. frictional and positive connection. For positive connection reinforcement are connected with the connection such as bodkin, tie and hooks, nut and bolt etc. Frictional connections are connection which are purely designed considering long term connection strength with the interface between geogrid and facing. Here the aim of study is to check the designs for Reinforced soil wall with block facing, with consideration of secondary geogrid for connection and compared with the design of reinforced soil wall without consideration of secondary geogrid, for connection. For comparison, seismic zone III (as per IS 1893, Indian standard) will consider for various design heights and compare the requirement of reinforcement and tensile strengths, in all cases. Merits and demerits are discussed in detail for the use of frictional connection, for higher seismic zones with the use of rod / pins etc., for additional resistance.

Keywords: *Reinforced soil wall, block facing, frictional connection, FHWA and BS 8006 guidelines*

## 1 INTRODUCTION

Geosynthetic reinforced soil wall have gained widespread acceptance due to their cost effectiveness over the conventional Reinforced Concrete structures. Reinforced soil wall consists of various components like backfill soil, reinforcement and various facing & connection options. Broadly, there are two types of connection system, one is positive connection and another is frictional connection. Frictional connections are those, where connection is purely due to the interface friction between reinforcement and facings. Generally various sizes of modular blocks are considered for frictional connection and connection strength shall be derived from the laboratory tests for different normal pressures. Designer has to check the connection load with available connection strength for each level of reinforcement to have adequate factor of safety for the design life of the structure.

There are two latest design philosophy being accepted worldwide, for design and analysis of reinforced soil structures, BS 8006-1:2010 and FHWA-NHI-0024 2010. As per BS 8006-1:2010, connection load shall be considered, 100% to 75% of tension requirement, for the layers, from bottom to top and check with the available connection strength at each level. Hence there is a reduction for connection load at top for BS 8006-1:2010. As per FHWA-NHI-0024 2010, 100% tension requirement shall be considered, for all the layers of reinforcement, bottom to top.

Usual practice, for designing reinforced soil wall is to carry out design with primary reinforcement at spacing of 600mm (for Block facing, width 300mm, height 200mm) and perform all the checks except connection check, satisfying factor of safety requirements. Once reinforcement type, length and spacing is finalised, connection checks shall be carried out. Connection checks can be performed in two ways, one is, by reducing spacing of primary reinforcement and other is considering secondary reinforcement to achieve required factor of safety, for connection.

There are different requirements for connection load, for various design standards. As per the requirements for additional connection strength, one has to consider secondary reinforcement, in between two primary reinforcements. Study shows that measured accumulated lateral wall facing deflections increased with the wall height and the maximum deflection occur at top of the wall. It has been also found that with the inclusion of secondary reinforcement, for connection, reduces the accumulated wall facing deflections.

Requirements for more connection strength are envisaged for higher seismic zones and for that use of secondary reinforcement will not only provide additional resistance for connection but also increase the facing stability by stabilizing soil near facings. Wherever long term connection requirement is not satisfied with secondary reinforcements, and/or, additional precautionary measures with mixed connection can be considered with the use of horizontal rod wrapped with geogrid, vertical pins connected with geogrid, geogrid wrapped by in between hollow portion of blocks to connect several blocks etc.

## 2 LITERATURE REVIEW

### 2.1 *Field tests*

Yan et al. (2016) conducted field tests to verify effects of secondary reinforcement on improved performance of RSW walls. In this study, three RSW wall sections were constructed and instrumented (1) RSW with uniaxial geogrid as primary and secondary reinforcement (TS1) (2) RSW with uniaxial as primary and biaxial as secondary reinforcement (TS2) (3) RSW with only primary reinforcements as uniaxial reinforcement (TS3).

Lateral thrust was applied on TS1, TS2 and TS3 for a wall height ranging from 11.3m to 11.9m. Vertical and lateral earth pressures, accumulated lateral wall-facing deflections, and strains of primary and secondary geogrid layers during construction is measured for all the above test sections.

It was observed that accumulated wall deflections at the top of wall were higher with primary reinforcement as shown in Fig 1. But inclusions of secondary geogrid reduced the accumulated wall facing deflections. Lateral Earth pressure increased linearly with depth of wall causing at rest earth pressure condition in the lower bottom due to existence of embedment. While in top portion of wall, lateral earth pressure were close to active earth pressure as the wall deflection was sufficient to allow the reinforced soil to be in an active state condition. Earth pressure coefficient at top portion of wall with only primary reinforcement were higher than wall with secondary reinforcement as seen in Fig 2. Secondary reinforcement carries a portion of tension force from lateral earth pressure and reduces tension force in the primary geogrid.

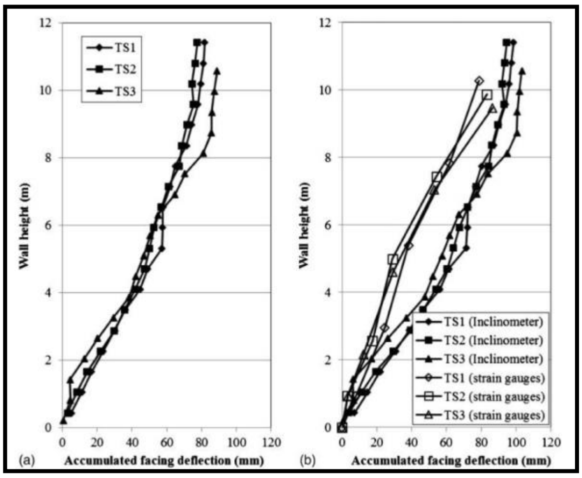


Figure 1. Accumulated Wall facing deflections (a) before (b) after backslope formation (Yan et al 2016)

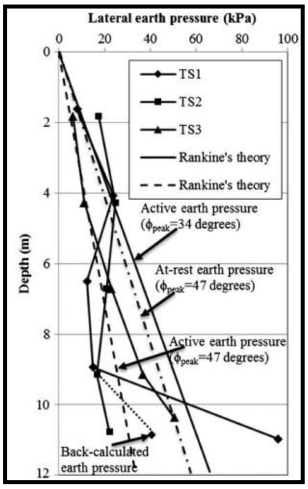


Figure 2. Measured Lateral earth pressure (Yan et al 2016)

### 2.2 *Laboratory Connection Test*

The Connection Pullout tests were performed as per the relevant FHWA, USA specifications in the geotechnical Engineering laboratory at IIT Madras. The width of the geogrid used in the tests was 600 mm which is more than the length of one typical block. Fig 4 shows the plan view of the arrangement of geogrid and one row of blocks placed above the grid. The infill aggregate can be clearly seen in the photograph. The deformation was measured at the midsection through an electronic LVDT as shown.

Figure 3. Arrangement to apply vertical load on the connection (TFI 2008)

The pullout force was applied through a hydraulic actuator that can be moved at constant displacement rate. The applied load and the pullout distance were measured through electronic readout units. Initially, constant vertical load was applied on the connection system. Then, the geogrid was pulled out at a constant rate of 15 to 20 mm per minute. The pullout distance was measured through a LVDT fixed centrally near the connection point as shown in Figure 3. The arrangement at the front-end is shown in the following photographs.

Figure 4. Arrangement for pullout of the geogrid from the connection (TFI 2008)

The tests were performed at different normal loads to simulate different heights of walls. Many of the tests were repeated to verify the consistency of the test data. The tests were performed at four normal load levels for all the Techfab grids. The loads corresponding to different pullout displacements were measured. The load at 20 mm displacement was noted as the serviceability limit load and the ultimate load was noted as the peak load. The failure was noted to by rupture for low strength geogrids while it was invariably by pullout for high strength geogrids. The following tables give the data for different geogrids at various normal load levels.

Table 1: Interface shear strength factors for connection between facing blocks and Techgrid Geogrids

| Sr. No. | Type of grid | Serviceability limit - (20mm) | | | Ultimate capacity | | |
|---|---|---|---|---|---|---|---|
| | | N (kN/m) | $a_{cu}$ (kN/m) | $l_{cu}$ (°) | N (kN/m) | $a_{cu}$ (kN/m) | $l_{cu}$ (°) |
| 1 | U-40 | 0-33 | 6 | 29 | 0-22 | 7 | 42 |
| | | 34-44 | 19 | 7 | 23-44 | 21 | 14 |
| 2 | U-60 | 0-33 | 6 | 40 | 0-44 | 13 | 38 |
| | | 34-44 | 29 | 10 | | | |
| 3 | U-80 | 0-44 | 13 | 36 | 0-44 | 20 | 40 |
| 4 | U-100 | 0-44 | 19 | 36 | 0-44 | 23 | 38 |
| 5 | U-120 | 0-44 | 20 | 37 | 0-44 | 23 | 37 |
| | | > 44 | 44 | 10.8 | > 44 | 54 | 2 |
| 6 | U-150 | 0-44 | 21 | 35 | 0-44 | 22 | 39 |
| | | > 44 | 39 | 16.7 | > 44 | 46 | 14 |
| 7 | U-200 | 0-55 | 22 | 37 | 0-55 | 25 | 37 |
| | | 56-100 | 55 | 10 | 56-100 | 58 | 9 |
| 8 | U-250 | 0-55 | 22 | 37 | 0-55 | 25 | 37 |
| | | 56-100 | 55 | 10 | 56-100 | 58 | 9 |

Interpretation of Results

The pullout load at 20 mm displacement and the peak pullout loads were plotted against the respective normal loads to determine the connection strength factors. The pullout loads at 20 mm displacement and peak loads at different normal loads are plotted. It could be seen that the connection strength increases with normal load and after a certain normal load, the connection strength remains more or less constant either because of pullout of grid or rupture at the facing connection.

The connection strength ($P_{cu}$) can be expressed in terms of the normal load (N) and the interface strength parameters $a_{cu}$ and $\lambda_{cu}$ as follows:

$$P_{cu} = a_{cu} + N*\tan(\lambda_{cu}) \quad (1)$$

Where $a_{cu}$ represents the connection strength in the absence of any normal load and the $\lambda_{cu}$ represents the rate of change of connection strength with unit increase in the normal load. These properties are similar to the Mohr-Coulomb strength factors for soils.

## 3 DESIGN ANALYSIS

The aim of this study is to analyze the connection strength for block reinforced soil wall section. The soil reinforcement is connected to the MBW units via a frictional, mechanical, or combination of mechanical and frictional type connection. Connection strength for this case is considered as purely frictional connection and results derived from laboratory study are used for calculations for connection strength and compared with connection load to check the requirements for secondary reinforcements.

In this study, Connection strength is analyzed using latest FHWA and BS 8006 guidelines. The software MSEW 3.0 was employed to examine the design of the test wall sections. MSEW 3.0, which was developed for the Federal Highway Administration (FHWA) and is used widely for the design of MSE walls worldwide. A capacity demanding ratio (CDR) was introduced in MSEW 3.0 for the design of MSE walls in 2006 and later was adopted by Berg et al. (2009). FHWA guidelines suggest the connection strength to be checked for 100% connection force exerted to facing at each reinforcement level. While BS 8006 suggests check for connection strength for 100% connection force at the toe of Reinforced soil wall and proportionately reducing to 75% connection force at the top portion of the RS Wall. The Parameters Considered for design are tabulated in table 2 as follows

Table 2: Input Soil parameters

| | |
|---|---|
| **Reinforced Fill** | |
| Unit weight (kN/m3) | 20 |
| Angle of Internal friction (°) | 32 |
| **Retained Fill** | |
| Unit weight (kN/m3) | 20 |
| Angle of Internal friction (°) | 32 |
| **Foundation Soil** | |
| Unit weight (kN/m3) | 18 |
| Angle of Internal friction (°) | 30 |
| Seismic zone | III |
| **Loads** | |
| Dead Load Surcharge (kN/m2) | 8.8 |
| Live Load Surcharge (kN/m2) | 24 |
| Vertical strip load (kN/m) | 24 |
| **Modular Block Dimensions** | |
| Height X Length X Width (m) | 0.20x0.45x0.30 |
| Unit weight (kN/m3) | 25 |

Design is carried out for two cases, as per BS 8006-1:2010, i.e. load Case A and load Case C. Tensile forces derived with load Case A (Factored load), are compared with ultimate connection capacity, without any increase in long term factor, hence the factor of safety for connection force to connection strength is 1.1 (fn-ramification factor). For second case, tensile forces derived with load Case C (Actual load), are compared with serviceability connection capacity (Connection capacity with 20mm displacement), with increase long term factor, as 1.5, hence the factor of safety for connection force to connection strength is 1.65 (fn x 1.5 = 1.65).

Similarly analysis has been done with FHWA-NHI-0024 2010 guidelines with load and resistance factors. Tensile forces derived in this case are with load factors and compared with serviceability connection capacity (Connection capacity with 20mm displacement), without any increase in long term factor, hence resistance factor for connection strength to connection force is 0.9 (as per FHWA guidelines, resistance factor is 0.9).

We have also compared the total tensile force requirements for three heights 3m, 6m and 9m, for BS 8006-1:2010 load Case A, BS 8006-1:2010 load Case C and FHWA-NHI-0024 2010, and plotted graph for comparison. Results are derived and tabulated for the height of 9m, for load Case A, load Case C BS 8006-1:2010) and FHWA-NHI-0024 2010, for connection checks.

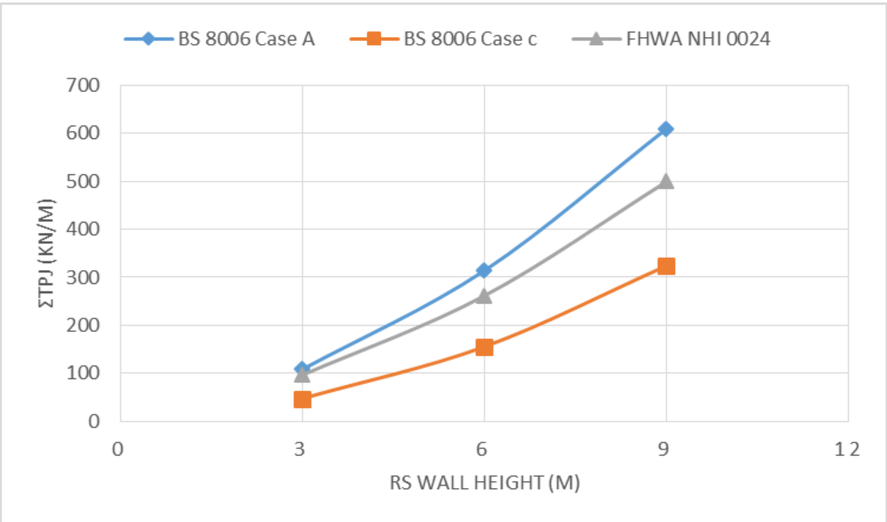


Figure 5. Comparison of ΣTpj for various wall heights with FHWA and BS 8006 methodology

## 4 RESULTS AND DISCUSSION

Results derived for three cases, BS 8006-1:2010 load Case A & load Case C, FHWA-NHI-10-024 2010, are tabulated below for connection checks.

For load Case A (Table: 3), Ultimate Connection load is compared with the Ultimate connection strength and check with factor of safety of 1.1. For bottom four layers, it is less than 1.1, hence considered secondary reinforcements to reduce Svj (spacing at jth layer), hence connection load is reduced to satisfy the required factor of safety.

For load Case C (Table:4), Serviceability check is performed and for that serviceability connection load is compared with serviceability connection strength with increased long term factor with targeted factor of safety equal to 1.65, and all the layers are passed for connection checks, no need for secondary reinforcement.

For analysis based on FHWA-NHI-10-024 2010 (Table:5), load factors are considered for connection load and so compared with serviceability connection strength with resistance factor and found requirement of secondary reinforcement at top five layers. To achieve required resistance factor, Secondary reinforcements were introduced at top and also change type of reinforcement for top three layers.

Table 3: Connection strength check as per BS 8006-1:2010 guidelines for 9m high wall for Ultimate Load Case A

| Layer No. | Level of reinforcement from bottom of RSW, m | Type of Geogrid | Ultimate tensile force in reinforcement, kN/m | Block height above geogrid Level, m | Normal Load over geogrid, kN/m | Ultimate Connection Strength, kN/m | Percentage based on reinforcement level, % | Ultimate Connection Load, kN/m | Partial Safety Factor | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.2 | TechGrid TGU-150 | 63.01 | 8.8 | 66 | 62.46 | 99.44 | 62.66 | 1.00 | NOTOKAY |
| 1A | 0.4 | TechGrid TGU-60 | 37.81 | | | 62.46 | 99.44 | 37.60 | 1.66 | OKAY |
| 1B | 0.6 | TechGrid TGU-60 | | | | | | | | |
| 2 | 0.8 | TechGrid TGU-200 | 70.08 | 8.2 | 61.5 | 67.74 | 97.78 | 68.52 | 0.99 | NOTOKAY |
| 2A | 1 | TechGrid TGU-60 | 46.72 | | | 67.74 | 97.78 | 45.68 | 1.48 | OKAY |
| 2B | 1.2 | TechGrid TGU-60 | | | | | | | | |
| 3 | 1.4 | TechGrid TGU-150 | 63.81 | 7.6 | 57 | 60.21 | 96.11 | 61.33 | 0.98 | NOTOKAY |
| 3A | 1.6 | TechGrid TGU-60 | 42.54 | | | 60.21 | 96.11 | 40.89 | 1.47 | OKAY |
| 3B | 1.8 | TechGrid TGU-60 | | | | | | | | |
| 4 | 2 | TechGrid TGU-150 | 58.07 | 7 | 52.5 | 59.09 | 94.44 | 54.84 | 1.08 | NOTOKAY |
| 4A | 2.2 | TechGrid TGU-60 | 38.71 | | | 59.09 | 94.44 | 36.56 | 1.62 | OKAY |
| 4B | 2.4 | TechGrid TGU-60 | | | | | | | | |
| 5 | 2.6 | TechGrid TGU-150 | 52.77 | 6.4 | 48 | 57.97 | 92.78 | 48.96 | 1.18 | OKAY |
| 6 | 3.2 | TechGrid TGU-120 | 47.85 | 5.8 | 43.5 | 55.78 | 91.11 | 43.60 | 1.28 | OKAY |
| 7 | 3.8 | TechGrid TGU-100 | 43.26 | 5.2 | 39 | 53.47 | 89.44 | 38.70 | 1.38 | OKAY |
| 8 | 4.4 | TechGrid TGU-100 | 38.96 | 4.6 | 34.5 | 49.95 | 87.78 | 34.20 | 1.46 | OKAY |
| 9 | 5 | TechGrid TGU-80 | 34.91 | 4 | 30 | 45.17 | 86.11 | 30.06 | 1.50 | OKAY |
| 10 | 5.6 | TechGrid TGU-80 | 31.07 | 3.4 | 25.5 | 41.40 | 84.44 | 26.24 | 1.58 | OKAY |
| 11 | 6.2 | TechGrid TGU-80 | 27.44 | 2.8 | 21 | 37.62 | 82.78 | 22.71 | 1.66 | OKAY |
| 12 | 6.8 | TechGrid TGU-60 | 23.98 | 2.2 | 16.5 | 25.89 | 81.11 | 19.45 | 1.33 | OKAY |
| 13 | 7.4 | TechGrid TGU-60 | 20.68 | 1.6 | 12 | 22.38 | 79.44 | 16.43 | 1.36 | OKAY |
| 14 | 8 | TechGrid TGU-60 | 14.63 | 1 | 7.5 | 18.86 | 77.78 | 11.38 | 1.66 | OKAY |
| 15 | 8.4 | TechGrid TGU-60 | 10.37 | 0.6 | 4.5 | 16.52 | 76.67 | 7.95 | 2.08 | OKAY |
| 16 | 8.8 | TechGrid TGU-60 | 9.10 | 0.2 | 1.5 | 14.17 | 75.56 | 6.88 | 2.06 | OKAY |

Table 4: Connection strength check as per BS 8006-1:2010 guidelines for 9m high wall for Ultimate Load Case C

| Layer No. | Level of reinforcement from bottom of RSW, m | Type of Geogrid | Serviceability tensile force in reinforcement, kN/m | Block height above geogrid Level, m | Normal Load over geogrid, kN/m | Serviceability Connection Strength, kN/m | Percentage based on reinforcement level, % | Serviceability Connection Strength, kN/m | Partial Safety Factor | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.2 | TechGrid TGU-150 | 35.55 | 8.8 | 66 | 58.80 | 99.44 | 35.35 | 1.66 | OKAY |
| 2 | 0.8 | TechGrid TGU-200 | 39.33 | 8.2 | 61.5 | 65.84 | 97.78 | 38.45 | 1.71 | OKAY |
| 3 | 1.4 | TechGrid TGU-150 | 35.35 | 7.6 | 57 | 56.10 | 96.11 | 33.98 | 1.65 | OKAY |
| 4 | 2 | TechGrid TGU-150 | 32.32 | 7 | 52.5 | 54.75 | 94.44 | 30.53 | 1.79 | OKAY |
| 5 | 2.6 | TechGrid TGU-150 | 29.18 | 6.4 | 48 | 53.40 | 92.78 | 27.07 | 1.97 | OKAY |
| 6 | 3.2 | TechGrid TGU-120 | 26.23 | 5.8 | 43.5 | 52.78 | 91.11 | 23.90 | 2.21 | OKAY |
| 7 | 3.8 | TechGrid TGU-100 | 23.45 | 5.2 | 39 | 47.34 | 89.44 | 20.97 | 2.26 | OKAY |
| 8 | 4.4 | TechGrid TGU-100 | 20.81 | 4.6 | 34.5 | 44.07 | 87.78 | 18.27 | 2.41 | OKAY |
| 9 | 5 | TechGrid TGU-80 | 18.30 | 4 | 30 | 34.80 | 86.11 | 15.76 | 2.21 | OKAY |
| 10 | 5.6 | TechGrid TGU-80 | 15.91 | 3.4 | 25.5 | 31.53 | 84.44 | 13.43 | 2.35 | OKAY |
| 11 | 6.2 | TechGrid TGU-80 | 13.61 | 2.8 | 21 | 28.26 | 82.78 | 11.27 | 2.51 | OKAY |
| 12 | 6.8 | TechGrid TGU-60 | 11.40 | 2.2 | 16.5 | 19.85 | 81.11 | 9.25 | 2.15 | OKAY |
| 13 | 7.4 | TechGrid TGU-60 | 9.28 | 1.6 | 12 | 16.07 | 79.44 | 7.37 | 2.18 | OKAY |
| 14 | 8 | TechGrid TGU-60 | 6.04 | 1 | 7.5 | 12.29 | 77.78 | 4.70 | 2.62 | OKAY |
| 15 | 8.4 | TechGrid TGU-60 | 3.96 | 0.6 | 4.5 | 9.78 | 76.67 | 3.03 | 3.22 | OKAY |
| 16 | 8.8 | TechGrid TGU-60 | 3.12 | 0.2 | 1.5 | 7.26 | 75.56 | 2.36 | 3.08 | OKAY |

Table 5: Connection strength check as per FHWA NHI 0024 2010 guidelines for 9m high wall

| Layer No. | Level of reinforcement from bottom of RSW, m | Type of Geogrid | Tensile force in reinforcement, kN/m | Block height above geogrid Level, m | Normal Load over geogrid, kN/m | Serviceability Connection Strength, kN/m | Partial Safety Factor | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.2 | TechGrid TGU-120 | 44.75 | 8.8 | 66 | 56.59 | 1.14 | OKAY |
| 2 | 0.8 | TechGrid TGU-150 | 51.01 | 8.2 | 61.5 | 57.45 | 1.01 | OKAY |
| 3 | 1.4 | TechGrid TGU-120 | 48.08 | 7.6 | 57 | 54.87 | 1.03 | OKAY |
| 4 | 2 | TechGrid TGU-120 | 45.16 | 7 | 52.5 | 54.01 | 1.08 | OKAY |
| 5 | 2.6 | TechGrid TGU-120 | 42.25 | 6.4 | 48 | 53.16 | 1.13 | OKAY |
| 6 | 3.2 | TechGrid TGU-100 | 39.35 | 5.8 | 43.5 | 50.60 | 1.16 | OKAY |
| 7 | 3.8 | TechGrid TGU-100 | 36.46 | 5.2 | 39 | 47.34 | 1.17 | OKAY |
| 8 | 4.4 | TechGrid TGU-100 | 33.58 | 4.6 | 34.5 | 44.07 | 1.18 | OKAY |
| 9 | 5 | TechGrid TGU-80 | 30.72 | 4 | 30 | 34.80 | 1.02 | OKAY |
| 10 | 5.6 | TechGrid TGU-80 | 27.89 | 3.4 | 25.5 | 31.53 | 1.02 | OKAY |
| 11 | 6.2 | TechGrid TGU-80 | 25.08 | 2.8 | 21 | 28.26 | 1.01 | OKAY |
| 11A | 6.4 | TechGrid TGU-60 | | | | | | |
| 11B | 6.6 | TechGrid TGU-60 | | | | | | |
| 12 | 6.8 | TechGrid TGU-60 | 22.31 | 2.2 | 16.5 | 19.85 | 0.80 | NOTOKAY |
| 12A | 7 | TechGrid TGU-60 | 14.87 | | | 19.85 | 1.20 | OKAY |
| 12B | 7.2 | TechGrid TGU-60 | | | | | | |
| 13 | 7.4 | TechGrid TGU-60 | 19.59 | 1.6 | 12 | 16.07 | 0.74 | NOTOKAY |
| 13A | 7.6 | TechGrid TGU-60 | 13.06 | | | 16.07 | 1.11 | OKAY |
| 13B | 7.8 | TechGrid TGU-60 | | | | | | |
| 14 | 8 | TechGrid TGU-80 | 14.29 | 1 | 7.5 | 18.45 | 1.16 | OKAY |
| 14A | 8.2 | TechGrid TGU-60 | | | | | | |
| 15 | 8.4 | TechGrid TGU-80 | 10.14 | 0.6 | 4.5 | 16.27 | 1.44 | OKAY |
| 15A | 8.6 | TechGrid TGU-60 | | | | | | |
| 16 | 8.8 | TechGrid TGU-80 | 9.03 | 0.2 | 1.5 | 14.09 | 1.40 | OKAY |

## 5 CONCLUSIONS

For purely frictional connection, connection load shall be checked for long term connection strength, to satisfy serviceability condition, for reinforced soil wall. There are various options to increase connection strength for frictional connections, reduce spacing of primary geogrid, add secondary reinforcements, develop mechanical cum frictional connection by means of connecting devises such as connector rod, pins etc.

Field cum laboratory studies prove that secondary reinforcement with the length of 1.0 to 1.5 meter length, will reduce the connection load and deformation of wall significantly compare to primary reinforcement alone. With inclusion of Secondary reinforcement, fill material nearby facing is stabilize and hence facing stability increases.

There are two design guidelines for reinforced soil wall, BS 8006 and FHWA. If we compare the connection load requirements for all the cases, total connection load requirement as per FHWA-NHI-10-024 2010 is in between the total connection load requirement for BS 8006 load Case A and BS 8006 load Case C.

According to BS 8006-1:2010 guidelines, connection load requirement reduces from 100% at toe to 75% at top of wall, hence the connection load requirement at top is reduced and for both cases load Case A and Case C there is no additional requirement for secondary reinforcement at top, for connection. On the contrary for ultimate connection capacity checks (load Case A), secondary reinforcement requirement is at bottom, due to higher connection load due to ultimate limit state but in serviceability limit state, with long term factor also, there is no requirement of additional resistance for connection. Hence, for connection capacity checks, as per BS 8006, there is no requirement for additional resistance for the seismic zone considered (Is 1893, Zone-III, India).

As per FHWA-NHI-10-024 2010, connection load is considered with load factor and so serviceability connection strength is compared with factored connection load, for resistance factor of 0.9. As per the analysis made, there is a requirement for secondary reinforcement and change in reinforcement type at top, to get required resistance factor. Design results are match with the study carried out, wherein more deformations are observed at top of the wall. Hence FHWA-NHI-10-024 2010 guidelines are more conservative for connection checks, compare to BS 8006 guidelines.

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