Considerations for Reinforced Soil Walls in Urban Flyovers

Rajiv GOEL
Managing Director
Earthcon Systems I Pvt. Ltd.
New Delhi, INDIA
rajiv@esipl.net

Mr. Rajiv Goel, an alumnus of BITS, Pilani (B.E. Civil, 1984-88) and IIT, Delhi (M. Tech., 1992-1994) is an active member of IRC and ING-IABSE. After serving with NITHE for about 4 years he joined M/s Tandon Consultants Pvt. Ltd. (TCPL) at Delhi in the year 1995. He is currently the Managing Director of Earthcon Systems (I) Pvt. Ltd. and apart from being a solution provider to the Highway Contractors, he is in active discussion with the fraternity through papers and presentations at NITHE, IRC and ING-IABSE.

Summary

RSW is an internally stabilized composite engineered mass and is being used for construction of approaches of flyovers/ ROBs in a big way. In urban context RSW has the principal advantage of aesthetics and minimizing land requirements apart from many inherent advantages like better seismic performance and economy. This is also a favorable method for faster construction.

Many aspects like reinforcing elements' types, facia types, design philosophies and appurtenances are discussed herein. A separate section has also been devoted to abutment-RSW interface as this is one aspect which definitely requires the attention of viaduct designers.

Keywords

Reinforced Soil Walls, Urban Flyovers, Flyover Appurtenances, Select granular fill, GI Steel Strips, Metallic Bar Mats, Welded / Twisted Coated Wire Mesh, Polymeric Grids: Geogrids, Woven Geo-Textile, Geo-Strap/Geo-Tie, Modular Blocks, Discrete Facia Panels, Hybrid block-panel facia, Abutment Interface, MSEW

1. Introduction

1.1. India has undertaken large infrastructure up-gradation projects and Reinforced Soil Walls (RSW) are being widely used for constructing high embankments due to various reasons such as limited right of roadway; to minimize land acquisition, poor founding soil conditions, aesthetics, economy considerations & ease of construction etc. The quantum of work has increased many folds and contractors have to choose from various available alternates by evaluating economy, aesthetic, durability and speed of construction.

1.2. RSW is an internally stabilized composite engineered mass; consisting of selected backfill, soil reinforcing elements and a non-structural/ optional facia.

1.3. In urban context the major advantages of RSW are aesthetics, limited site activity, ease of construction and usability in shallow urban services situations.

1.4. Facing is a component of the RSW used to prevent the soil from raveling out between the rows of reinforcement. Common facings include precast concrete panels, dry stacked modular blocks, gabions and wrapped sheets of geo-synthetics. The differential settlement tolerance of a RS wall with rigid facing, depends solely on the flexibility of the facing.

1.5. The RSW is a flexible mass and can tolerate large total and differential settlements. However, since in majority of the cases it is used as approach to a ROB/ flyover structure (which is generally resting on non-yielding type of foundations e.g. RCC piles), marrying the two differently behaving systems requires special attention.

1.6. There were many myths associated with the technology and often phrases like "proven technology", "proprietary and/or patented systems" etc. are still being used by the engineers to shield their ignorance. In many situations test results and material certifications are ignored and System Certifications from BBA/ HITEC etc. are insisted upon. This thought has to change.

1.7. Appurtenances like surface drainage, sub-surface drainage, crash barrier and corner units etc. play a very important role in the overall performance and aesthetics of the whole structure and needs to be addressed in detail. Often a good RSW construction is overshadowed by the badly designed and constructed appurtenances.

2. Advantages and Disadvantages of RS Walls

2.1. **Advantages**

RS walls have many advantages compared with conventional reinforced concrete and concrete gravity retaining walls. Some of these are:

- They use simple and rapid construction procedures and do not require large equipment
- They need less space in front of the structure for construction operations
- They do not need rigid, unyielding foundation support
- They are cost effective and aesthetically pleasing

Fig. 1: RCC walls

Fig. 2: RS walls

The relatively small quantities of manufactured materials required, rapid construction, and competition among the developers of different systems has resulted in a cost reduction relative to traditional types of RCC retaining walls. RS walls are economical than other wall systems for walls higher than about 3m or where special foundations would be required for a conventional wall.

One of the greatest advantages of RS walls is their flexibility and capability to absorb deformation due to poor subsoil conditions in the foundations. Also, based on observations in seismically active zones, these structures have demonstrated a higher resistance to seismic loading than rigid concrete structures.

2.2. **Disadvantages**

The following general disadvantages may be associated with RSW:

- Require a relatively large space behind the wall to obtain enough wall width for internal and external stability.
- RS walls require select granular fill (at sites where there is a lack of granular soils, the cost of importing suitable fill material may render the system uneconomical).

2.3. **Some Limitations**

- The design and construction of soil-reinforced systems often requires shared responsibility between system designer, material suppliers and owners, and

- Greater inputs from geo-technical specialists are required in a domain often dominated by structural engineers.

3. Reinforcing Elements' Types

A variety of reinforcing element types are used for constructing RS walls and RSS as listed below:

3.1. **GI Steel Strips**

Ribbed steel strips are used in India for long time. These are galvanised with a zinc coating of about 1000gm/sqm. However as per recent codes this zinc coating can be thinner and requires that increased sacrificial thickness should be assessed and incorporated in design suitably.

Fig. 3: GI Steel Strips

Plain strips can also be used as reinforcing elements but result in under-utilisation of steel strength as lower friction development compared to ribbed strips, results in more number of strips. The ratio of friction developed on plain vis-à-vis ribbed strips is about 0,4: 1,5. The higher requirement of steel quantities precludes the use of plain strips as reinforcing material.

3.2. **Metallic Bar Mats**

Many systems used metallic bar mats (or mats of metal) under the name Retained Earth. Metal mats are made using plain cold drawn wires, fusion welded with cross wires and the assembly is then hot dip galvanized. The spacing of the cross elements is constant throughout the length of the metal mat.

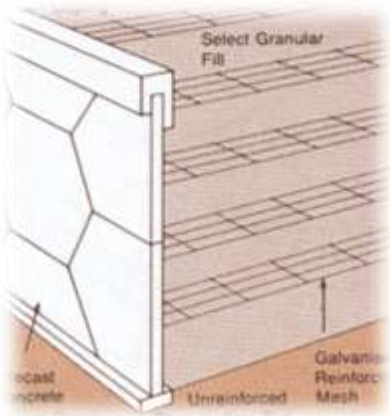

Fig. 4: Metallic Bar Mats

3.3. **Welded / Twisted Coated Wire Mesh**

Galvanised and/or polymer coated twisted wire mesh is also used as a reinforcing material. Same wire mesh can also be used to form the gabion facia filled with stones. By far this is the most flexible facia.

3.4. **Polymeric Grids: Geogrids**

With the use of polymeric geogrids a whole new chapter has been written in the field of RS walls and slope construction. There are primarily two types of geogrids that are being used at present:

- HDPE and
- PET (Polyester) geogrids

Fig. 5: Polymeric Grids: Geogrids

3.5. **Woven Geo-Textile**

Woven Geotextiles have been used successfully for building reinforced soil walls. These walls are susceptible to large post construction deformations due to high strains developing in the fabric. Their major usage still remains for the construction of reinforced soil slopes.

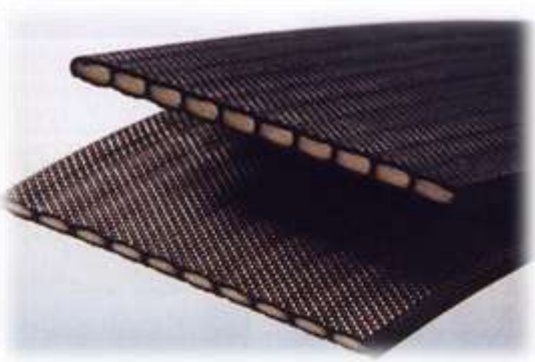

Fig. 6: Geo-strap/ Geo-Tie

3.6. **Geo-Strap/Geo-Tie**

Geo-straps are wide bands of polymeric polyester yarn bundles coated with HDPE/PVC while it is manufactured. The product has good resistance to installation damage.

4. Facia

The RSW facia require special attention especially in urban context. In majority of the urban flyover constructions two types of facia are used viz. Modular Blocks and Discrete Panels.

4.1. **Modular Blocks**

- Blocks are manufactured by dry-cast process using a block making machine, wherein zero slump concrete is poured into the mould, compacted and ejected immediately. The locally available machines, which are either manual or semi-automatic, produce inadequate vibration and compaction. This results in inferior quality of blocks, which lack strength and durability. Use of large machines is not viable because of small quantities involved.

Fig. 7: Semi-automatic block casting machine

- Although majority of the tender specifications call for M35 concrete grade of facia, in the opinion of the author not more than M25 concrete is achieved in these blocks.

- Block walls are constructed with batter ranging from 3^o to 6^o. In case of a 10m high wall, a block wall (with 6^o batter) will require 2.1 m additional space beyond the carriageway (both sides put together).

- It is required to place a 600mm wide filter media behind the blocks, with a full layer of geotextile sandwiched between filter media and RE fill. The cost of filter media and geotextile is high. Also the process of placement of textile is time consuming.

- The bocks are unreinforced and hence save on the cost of reinforcement. The average depth is about 300mm, but the concrete consumption is about $0.2m^3/m^2$. The remaining $0.1m^3/m^2$ is hollow space, which is filled with single size aggregates.

- Blocks are handled manually and crane is not required. Also any propping or any special T&P is not required. The blocks are prone to move due to vibration of the roller. Hence, the alignment of the wall is likely to get disturbed. For high walls, it is difficult to control the alignment of the walls.

- Due to small size of blocks, it is not possible to provide good architectural finishes (except using color concrete) in the segmental block walls. It is not possible to provide organization logos on the segmental blocks.

Fig. 8: Manual Handling of Blocks

Fig. 9: Manual Handling of Blocks

Fig. 10: Color Blocks

- Under the seismic loading, the normal load shall reduce resulting in corresponding reduction in the connection strength. Hence, as per FHWA-NHI-00-043 document, frictional type connections should NOT be used where seismic Peak Ground Acceleration (PGA) is > 0.19g. Thus block walls cannot be used for seismic zones IV (PGA 0.24g) and V (PGA 0.36g).

4.2. **Discrete Facia Panels**

- Discrete panels ate produced by pouring concrete into the steel moulds and compacting using needle / form vibrators. The concrete in the panels is vibrated and hence required strength and durability is achieved. M35 concrete strength is achieved easily.

- The concrete can be produced and handled with existing facilities and at a lower cost. No separate arrangement like a handi mixer etc. is required. Also the cost of concrete and its production is as per standard norms. The panel finish is superior to those of dry cast blocks.

Fig. 11: Mechanical Handling of Panels

- Panel Walls can be constructed with zero batter (with steel strips and geo-strap/tie) or with nominal batter of 1.5^{o} (i.e. 1 in 40), thus minimal extra space is required beyond the carriageway width.

- Because of the different types of panels (in terms of panel sizes and spacing of fixtures embedded in the panel) casting schedule has to be carefully planned as per approved drawings and the erection plan.

- The filter media is only 300mm and the textile is required only over panel joints in bands/ strips. The cost of glue is additional.

- The concrete consumption for panels is about 0.14 to 0.18 m^3/m^2. The consumption of steel reinforcement is about 4.0 to 5.0 kg/m^2.

Fig. 12: Aesthetic finish of Panels & Organization Logos

- Due to large size of facia panels, erection speed of over 100 Sqm /day can be easily achieved with one erection gang comprising of 8 to 10 workers and one crane. Each panel is equivalent to about 25-36 nos. of blocks.

- Due to large size of facia panels it is possible to provide very good architectural finishes to the facia panels. Logos of the organizations can be inscribed on the Facia panels.

Fig. 13: Aesthetic finish of Panels

- The longitudinal and transverse facia flexibility is achieved using pre-defined panel joints with flexible packing/ air gap.

- The mechanical connection is designed for all possible strengths of reinforcing elements used.

- The method of evaluation of reinforcing element design force is dependent on the type of reinforcing element used. Two methods of analysis are used viz. Tie Back Wedge Method (for extensible reinforcements like geogrids, k_{active} used for earth pressure evaluation) and Coherent Gravity Method (for inextensible reinforcements like steel strips and geo-straps, k_0 used for earth pressure evaluation). It is unfortunate that some of the suppliers using geo-straps design their walls using tie back wedge method. This practice of under-designing requires correction.

Fig. 14: Aesthetic finish of Panels & Organization Logos

4.3. **Hybrid block-panel facia**

In the recent times, the use of hybrid block-panel system has become popular because of the inherent economy. The size of the facing unit is in the range of 1400mm (L) x 600mm (H) x 210mm (D) and is reinforced. The facia has no mechanical connectors for the geogrids. The grids are spaced at a constant spacing of 600mm (equal to the height of the facia) and are attached to the facia using frictional connection. Laboratory tests have been conducted in some reputed academic institutions to establish the efficacy of the connection.

Fig. 15: Hybrid Block Panel Facia

However, the fundamental principal of unreinforced modular blocks' wall behavior under longitudinal differential settlements has been ignored. The facia has to tolerate longitudinal differential settlements [restricted to below 0.5% (1 in 200) for unreinforced block walls], which is a must for the facia stability. Under the longitudinal differential settlements the unreinforced block can crack (being unreinforced) or articulate (because of their small dimensions), and hence are able to retain the connection strength.

This behavior is absent in the reinforced large sized block-panel. Under longitudinal differential settlements, the large sized reinforced block-panel cannot crack or articulate, and hence cannot retain the connection strength, required for facia stability. This is also more susceptible to damage under seismic activity. Use of such facia system must be avoided.

5. Tolerance For Settlement/ Abutment Interface

5.1. One of the greatest advantages of RS walls is their flexibility and capability to absorb large deformation due to poor subsoil conditions in the foundations. In fact how much settlement the reinforced soil mass can absorb is solely limited by the flexibility of the facia.

5.2. Axial rigidity of the facia is another important issue that needs to be looked into for desirable performance of high RS walls. The reinforced soil mass shall get compacted with time and would drag the reinforcing element with it. Please note that we are discussing the reinforced soil mass alone and not the foundation soil. In case of RS wall constructions with hard facing, the reinforcing element is connected with the facing and such downward dragging of the reinforcing element would overstress the connection. The facia should have axial flexibility to accommodate the same. Introducing compressible pads between the panels' horizontal joints can cater for it, but it is important that the pads are not solid pads as the same would possess low compressibility, and the purpose would be lost.

5.3. The flexibility of the RS walls is often not utilised to its fullest extent primarily because of psychological reasons. On many projects ground has been dug for many meters to overcome the fear of excessive settlement.

5.4. RS wall and abutment pier interface is another issue, which needs to be looked into. It is certainly not acceptable to have a RS wall settling differentially w.r.t. to the non-yielding abutment by a large amount as this would impair the riding quality.

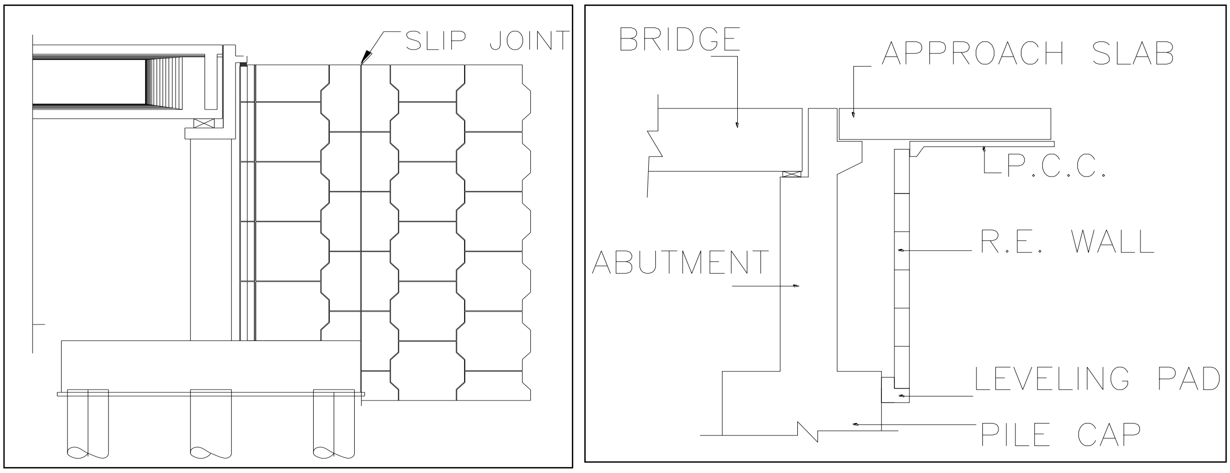

Fig. 16: Alternate arrangement at Pile Cap RSW interface

5.5. Generally for flyovers, the abutment support is identical to the intermediate supports viz. a non-yielding type, and an interface with the RS wall has to be conceived and designed. The RS wall is sitting on a yielding strata and the design philosophy has to marry the two differently behaving systems without causing distress in any of them.

Fig. 17: Hybrid Abutment and Pure Load Bearing Abutment

5.6. At times it is insisted to bring the cross wall closer to the abutment and hence the RS wall has to sit on the unyielding support e.g. a pile cap. The junction of this transition should be provided with a vertical slip joint to avoid panel cracking. Although it is much better to stop the cross-wall before the pile cap and let the approach slab or any other structural system span the gap thus created. The former solution, though correct, is inferior to the second one.

5.7. The maximum height of the approach occurs near the abutment and results in maximum settlement at the interface, further aggravating the problem. Ground improvement would invariably be required to limit excessive settlement near the interface. The length of approach where ground improvement can be carried out can be reasonably limited to 20-30m near the abutment.

5.8. Many solutions are possible to avoid the need of this ground improvement viz.:

- Adopt pure load bearing abutment i.e. let the super structure rest on the bank seat supported by the RS walls,
- Redesign the abutment foundations to increase its settlement, thus reducing the differential settlements, and lastly
- Shift the cross RS wall away from the rigid abutment shaft and let the suitably designed approach slab span the gap.

5.9. All the above solutions are definitely feasible for simply supported spans. For continuous spans, analysis needs to be carried out to assess the impact of additional differential settlement on the structural system. The cost of ground improvement vis-à-vis the cost of additional structural strengthening required needs to be compared. Changing the structural system to simply-supported is also be a feasible solution.

6. Appurtenances

A list of appurtenances discussed in the following sections include surface drainage, sub-surface drainage, crash barrier & friction slab, corner unit and panel joints.

6.1. Surface Drainage

On approaches to flyovers/ bridges etc. the surface runoff has to be drained out without having it to travel for long distances on the sloped approaches. The crash barrier and the friction slab arrangement have to accommodate a collection chamber and pipe to collect and drain out the water. It is important that the drainage pipe should be hugging the wall else there are chances of it getting damaged apart from looking ugly. It is also possible to cover the pipes with precast units having the same finish as the precast panels.

Fig. 18: Drain Pipe covered with precast pieces of similar finish

6.2. Sub-Surface Drainage

Fig. 19: Drain Pipe without any cover

Sub-surface drainage has to be designed for draining out water entering the reinforced embankment. As already mentioned, the flyover approaches are black topped minimizing the water ingress level to insignificant levels. However, whatever little may be the amount it should be drained off to avoid development of pore water pressure within the reinforced soil mass, a condition it is not designed for. A drainage gallery / separation layer is generally provided behind the facia and the water is allowed to go through the facing joints. Alternately, the facing joints can be covered with filter fabric so that only the water is allowed to go out and does not carry the backfill along.

It has also been observed that many a time half perforated pipe wrapped in filter fabric is provided near the outside ground level to collect and drain out the water. The fact remains that since the water ingress is low, reinforced fill is self-draining and the facia is not water tight, the water will never reach the pipe. The provision of pipe is especially suited for landscaped applications where the top is permeable and allows substantial water ingress. For normal flyover construction this provision is redundant and a shear waste of money apart from creating constructional difficulties.

6.3. **Crash Barrier & Friction Slab**

Crash barrier over the reinforced soil walls is provided along with a friction slab to provide stability during a vehicular impact. Not explicitly shown in the picture is the fact that the crash barrier is not touching the facia panels and derives its support from the reinforced fill through the friction slab.

Fig. 20: In-situ crash barrier construction vs Precast Crash Barrier construction

The practice to build crash barrier is to pack the space around the crash barrier with foam and cast it in-situ. The other option is to precast the facia unit erect it in place and cast the in-situ friction slab. The third option, which has also been used, is to cast the entire unit along with the friction slabs in suitable modules and erect it in place.

Fig. 21: Precast Crash Barrier construction: various options

There are many types of shapes and finishes that have been used for crash barrier.

It is necessary to standardize the design, dimensions (to the extent possible) and the main rebar so that it is not necessary to evolve design and drawing for every RS wall project. Apart from repetitions of the effort, at times imaginary designs are evolved.

6.4. **Corner Unit**

At the junction of long wall and the cross wall, a corner unit has to be introduced for transition. With modular blocks it is quite easy to make the transition by cutting the blocks suitably. With panels a special unit has to be designed and provided at the corner. This unit can be easily precast and erected like all other panels. It is sad to see some ugly looking in-situ construction being done in the corner. These in-situ reinforced constructions eventually crack and become an eye soar.

Fig. 22: Precast corner units

Fig. 23: c/o in-situ corner unit

6.5. **Panel Joints**

In addition to controlling the facia flexibility and permitting drainage of water, the panel joints play a major role in the overall performance of the RS wall construction.

The joints are always made with a tongue and groove arrangement, which is often wrongly considered as a mechanism for interlocking the panels. In fact the panels are never touching each other unless there is severe differential settlement of the founding soil, causing panel movement and possible interlocking and cracking of the panels.

6.6. **Extent of RSW**

In urban flyovers it is customary to provide the RSW upto the end (at the lower end). Though mathematically it may be economical to build some part of the low height approach in the form of RCC walls, it is not advisable from aesthetics point of view. Also form construction point of view it is an additional cast-in-situ activity which the contractor needs to undertake. Constructing this odd 50m wall in RSW is very easy and can be completed within no time.

7. Design Principles including Aseismic Design

7.1. The design of reinforced soil walls is quite straightforward and a number of codes/manuals are available for the same viz.:

- AASHTO LRFD Bridge Design Specifications – 2012
- BS: 8006-1: 2010: Code of practice for Strengthened/Reinforced Soil and other fills

Out of the above, in author's opinion, AASHTO is the most comprehensive and simplified code and BS the least, which is more of a philosophical code.

7.2. Apart from above many publications from Federal Highway Administration (FHWA) are available highlighting the design and construction aspects. The publication nos. are FHWA-NHI-10-024 and FHWA-NHI-10-025. These can be downloaded from FHWA website.

7.3. The design primarily consists of two major aspects viz.

- Internal stability and
- External stability

7.4. **Internal Stability**

Internal stability consists of three checks on the reinforced soil mass:

- Pull out overstress: to ensure that the tensile force developed in the reinforcement is transferred to the embedment zone safely with a factor of safety (FoS) of 1.5.

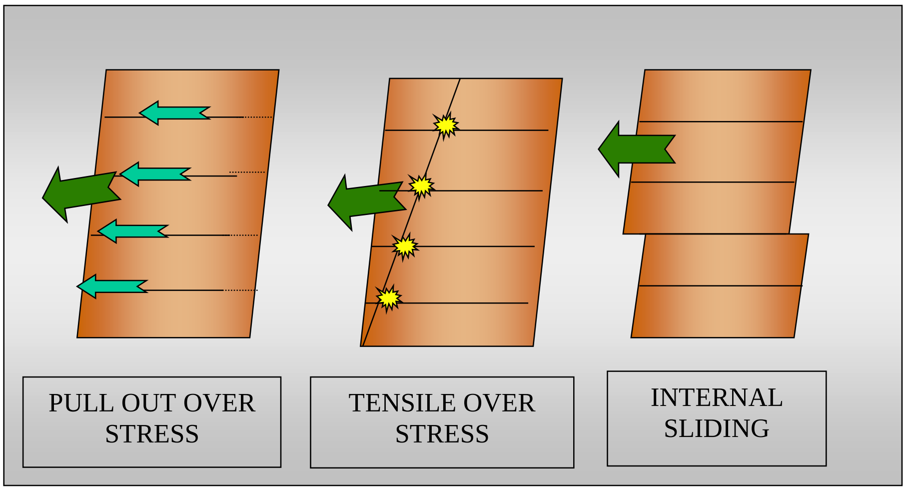

Fig. 24: Internal Stability Checks

- Tensile overstress: to ensure that the tensile force developed in the reinforcement is carried by the reinforcing element safely with its long-term design strength with a FoS of 1.5.

- Internal sliding: to ensure that the reinforcing element are long enough to mobilize frictional resistance sufficient to prevent sliding of a part of the reinforced fill over the sheet of reinforcing element under the lateral thrust from the retained fill. This check is required only for planar reinforcing element such as geogrids/geotextiles with full coverage only.

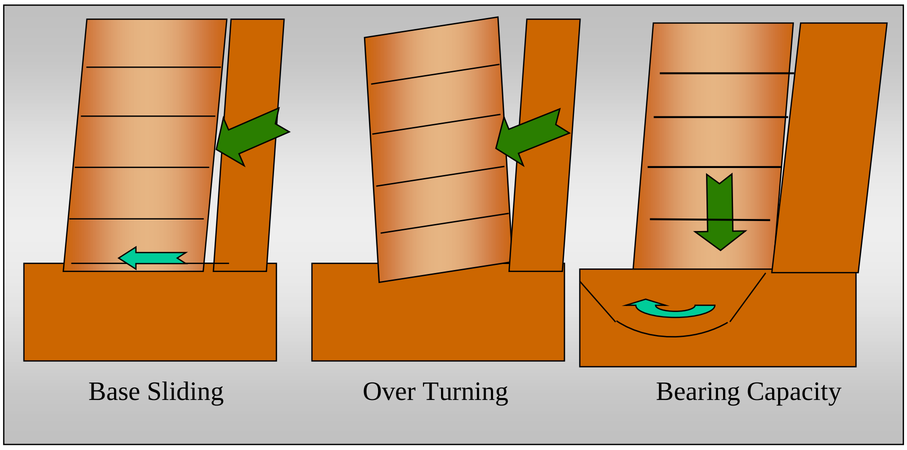

Fig. 25: External Stability Checks

7.5. **External Stability**

External stability checks consist of checks for the foundation soil and reinforced soil mass similar to a retaining wall assuming the reinforced soil mass as one coherent entity.

The first two checks are seldom critical. The bearing capacity should be evaluated using general shear failure with a factor of safety of 2.0. Settlement analysis is performed separately and analyzed in relation to facia flexibility. Ground improvement to increase bearing capacity is seldom necessary except for exceptionally poor founding soils conditions.

7.6. **Global Stability**

Global stability analysis is not necessary for routine structures, unless the reinforced soil wall is founded on a slope, which itself may become unstable in the process. Global stability analysis shall be necessary for poor foundation soils, complex geometries like superimposed RSWs.

7.7. **Facia Stability**

Facia stability is critical for Segmental Retaining Walls (SRW) and consists of three checks.

The checks are critical for large spacing e.g. $\geq$600mm of reinforcing elements and should invariably be performed.

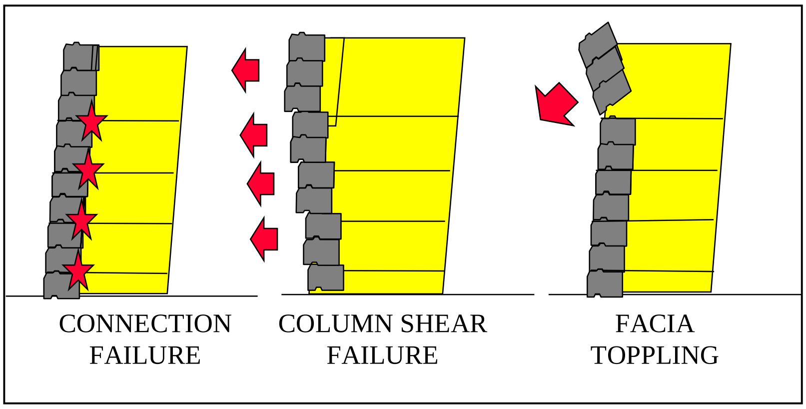

Fig. 26: Facia Stability Checks

7.8. **Aseismic Design**

Aseismic design is performed based on the Mononobe-Okabe analysis (M-O) method depending on the peak ground acceleration expected at site. The maximum ground acceleration expected at any site is as given in IS: 1893:2002 and summarized below:

Seismic Zone	*Peak ground acceleration, A*
II	0.10g
III	0.16g
IV	0.24g
V	0.36g

The M-O method is a pseudo-static method. Peak ground acceleration is converted to the structure acceleration Am using the equation:

$$Am = (1.45 – A) A$$

External Stability computations (i.e. sliding, overturning and bearing capacity) shall be made by including, in addition to static forces, the Lateral Inertial Force (P_{IR}) acting simultaneously with 50% of the Dynamic Earth Pressure (P_{AE}) to determine the total force applied to the wall. The Dynamic Earth Pressure (P_{AE}) is applied at a height of 0.6H from the base for level backfill conditions. Multiplying the weight of the reinforced wall mass by the acceleration Am, with dimensions H (wall height) and 0.5H, assuming horizontal backfill conditions, determine the Lateral Inertial Force (P_{IR}). P_{IR} is located at the centroid of the structure mass. These forces are determined using the following equations:

$P_{AE} = 0.375\ Am\ \gamma_f\ H^2$	Dynamic Earth Pres.
$P_{IR} = 0.500\ Am\ \gamma_f\ H^2$	Lateral Inertial Force

Factors of safety against sliding, overturning and bearing capacity failure under seismic loading may be reduced to 75% of the factors used for static conditions.

Internal Stability computations include design of reinforcement to withstand horizontal forces generated by the active wedge inertial force (P_I) in addition to the static forces. The facing inertial force can be neglected for thin facing but should be included for block walls. The total inertial force P_I shall be considered equal to the weight of the active zone times the maximum wall acceleration coefficient Am. This inertial force is distributed to the reinforcement proportionally to their resistant areas on a load per unit of wall width basis as follows:

P_I = Active wedge mass * Am

T_{md} = P_I * Lei / Σ Lei

The dynamic component of the reinforcement load (T_{md}) is added to the static component to find out the total load. For seismic loading conditions, the value of F* (the pullout resistance factor) shall be reduced to 80% of the values used in the static design. Factors of safety under combined static and dynamic loads for pullout and tensile capacity of reinforcement may be reduced to 75% of the factors of safety used for static loading.

8. Indian Scenario

Indian RSW market is huge and is becoming increasingly competitive. System suppliers have innovated new connection systems and adopted reduced coverage with geogrids to economize on designs, which is a welcome step. In fact India is the first country in the world to have adopted PET geogrids with facia panel way back in 2002 for Kanpur Bypass on NH2. Ever since this has become the most prevalent system of RSW construction in India. The general trend overseas is to use PET geogrids with modular blocks. Use of HDPE geogrids with facia panels is well established for long.

The most popular reinforcing element types in India are PET geogrids, geo-straps, steel strips and metal bar mats, in decreasing order of popularity. The major RSW system providers in India are (in alphabetical order) Earthcon Systems India Pvt. Ltd., Geosys India Pvt. Ltd., Maccaferri Environmental Solutions Pvt. Ltd., Reinforced Earth India Pvt. Ltd., Strata Geo-systems India Pvt. Ltd., Techfab Industries Ltd. and VSL etc. There are many manufacturers of PET geogrids in Indian market viz. Techfab Industries Ltd., Strata Geo-systems India Pvt. Ltd., CTM Geosynthetics and Maruti Rubplast Pvt. Ltd. Steel strips are rolled out of billets produced by SAIL etc. by steel rolling mills. Major *Steel Strips* and *Metal Bar Mats* system suppliers in India are Earthcon System India Pvt. Ltd., Reinforced Earth India Pvt. Ltd. and VSL.

Reinforced Soil Slopes (RSS) are rarely adopted and so are load bearing abutments.

There is no IRC code/ guidelines for design and construction of RSWs. Reference is generally made to AASHTO'2012/ FHWA codes/guidelines and/or BS: 8006-2010 code. BS code has a severe limitation that it does not include seismic design and reference has to be made to AASHTO/ FHWA for same. However even if one is able to assess the design seismic force using AASHTO, there is no guidelines in the BS code on how to design for this force. Author's view point is already presented earlier in the paper and is reproduced for clarity viz. "*AASHTO is the most comprehensive and simplified code and BS the least*".

AASHTO/ FHWA codes are sufficiently comprehensive and hence there is no immediate need for an IRC design code for RSWs. However, construction guidelines for RSWs by IRC would be a welcome step.

The Indian market, till recently was plagued with many misgivings. There were many myths associated with the technology and often phrases like "proven technology", "proprietary and/or patented systems" etc. were used by the engineers/ clients to shield their ignorance. In many situations test results and material certifications are ignored and System Certifications from BBA/ HITEC etc. are insisted upon. This thought has to change. What is pertinent is the use of certified materials and standard design procedures, which are well documented. A stringent quality control during material procurement and construction stage would bring better results, rather than a System Certifications from BBA/ HITEC etc. which are often carried out with non-representative material samples and recommendations are flouted by system suppliers themselves.

9. Conclusions

RSW is a flexible construction and its full potential need be utilised. Structural engineers need to appreciate this fact. Abutment –RSW interface need special attention and some thoughts have been shared in the paper. International codes like AASHTO and/or BS are often used for design and the need for an IRC design code is not felt by the fraternity. However, construction guidelines for RSWs by IRC would be a welcome step.

10. References

i. Publication no. FHWA-NHI-10-024, "*Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume I*", US DoT, Federal Highway Administration, November 2009, Ryan R. Berg, P.E.; Barry R. Christopher, Ph.D., P.E. and Naresh C. Samtani, Ph.D., P.E.

ii. Publication no. FHWA-NHI-10-025, "*Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume II*", US DoT, Federal Highway Administration, November 2009, Ryan R. Berg, P.E.; Barry R. Christopher, Ph.D., P.E. and Naresh C. Samtani, Ph.D., P.E.

iii. AASHTO LRFD Bridge Design Specifications – 2012

iv. BS: 8006-1: 2010: Code of practice for Strengthened/Reinforced Soil and other fills

v. "*Seismic Design and Performance of RS Retaining Structures*", Nov'19-21, 2001, Taipei, Taiwan ROC, International Geo-synthetics Engineering Forum

vi. Paper No.520 "*Mechanically Stabilized Earth (MSE) Walls & Reinforced Soil Slopes (RSS) Indian Scenario: A Comprehensive Review", IRC Journal, Rajiv Goel*

vii. *"Review of design procedure of various earth retaining structure including seismic effect"* Journals of the IRC vol. 72-3 Oct-Dec 2011, Lucknow