# "GEOSYNTHETICS: INNOVATIVE SUSTAINABLE SOLUTIONS FOR CIVIL ENGINEERING PROJECTS – CASE STUDIES"

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## 1.0 Introduction:

Problems of poor land foundations, non availability of standard materials for earth fills, earthquake effects such as liquefactions, soil hydraulics problems of scour, erosion, piping and recreation of lost land etc. can be resolved by applications of last decade's technology using Geosynthetics.

Lack of applied R & D work, intensive marketing of wide range products by different companies and inertia of professional practitioners – designers / contracting firms to adopt new, unproven, technology has restricted use of geosynthetics. There is little confidence available to introduce such technology in general. Though used extensively now, use is restricted to problems with no conventional solution, meeting cost, time and constraints of construction such as underwater etc.

**2.0** The Geosynthetics mostly used covers,

a) Woven, Non-woven Geofabrics of polypropylene, polyester, with different apertures, weight/$m^2$ and tensile strength.
b) Geogrids,
c) Georope, Gabbions - mattresses with 8 to 10 mm ropes, Geobags
d) Galvanized wire mesh Gabbions - mattress PVC coated,
e) HDPE, LLDPE, PP - thickness 0.75 to 3.0 mm with 1.8 to 4.6 m widths extruded polymeric membranes with normal or texturised rough surface.

There are products with its application prescribed by manufactures. It is very pain taking to technically digest local geotechnical problems to confirm properties as per ISO / local codes. There are hardly any reputed standard product certification research centers though attempts are on to create 2 - 3 centers of excellence by Government of India, Ministry of Textile.

## 3.0 Scenario around Surat / Gujarat:

The fastest growing urban center has its own problems. Disasters of frequent floods, coastal erosion and misbehavior of expansive soils (black & yellow). Underwater constructions have dominated problems faced by civil engineering designers and contractors. The problems related to fast development of infrastructures – roads, flyovers, bridges, water resources, storm drains, higher & higher structures, land, river training for erosion, scour in delta (meandering reach), and industrial structures – vibrations, are common. Recreating lost land in flood is challenge to Civil Engineering.

In general, the top soil is CH expansive 2 - 4 m overlying silt or silty fine sand with water table varying from 2 to 20 m as shown in Fig. 1. The network of canals through extended city has cyclical flooding of areas. The river on both sides & sea has high tide variations of 3 to 4 m daily. The exploration for site influenced by subsoil tide / canal seepage provide deceptive filed records of SPT, UDS and bore logs and problems of dewatering.

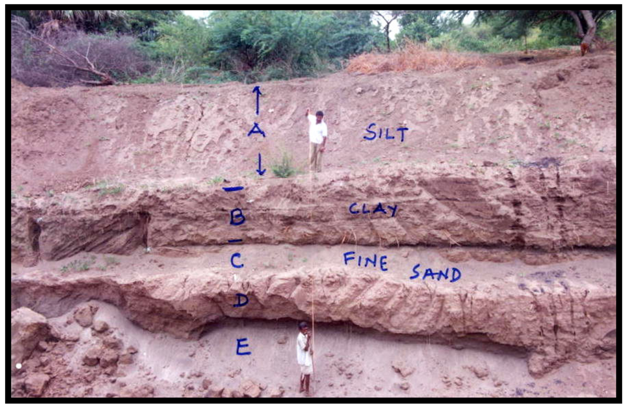


Fig.1: Soil stratification of left Bank. Base of embankment, Layer C, E caused cavity by Sand flow in return tides. Collapse of Bank – piping perpendicular to profile.

The normal new activity starts post budget for construction i.e. April to stop by June only (due to rains). The local & river flood could flood most of the areas in city by 1 to 2 m of waters for week or so. Thus subgrade, foundation, subsoil could swell and shrink in 40ºC of March - April heat.

The sites of major industrial sectors are old tidal sectors which are planned by dykes or massive compacted earth-fill to make plot. Heterogeneity of alluvial & made up grounds in creeks pose construction problems for foundations – dewatering, heaving, settlement, shrinkage, soil boiling, over dry spell.

## 4.0 Geotextiles – Polymeric Materials:

The widely used products by Civil Engineers are:

- Geotextile woven, with wide range of textile strength 40 to 400 kPa with elongation at failure 40 % to 12 %.

  The wide range of apertures and permeability are available starting from 75 micron. The usual specifications prescribed yarn i.e. Polypropylene / Polyester, width of fabric and its UV stability. It is used as filter separator and tensile reinforcement by selection of fabrics.

- Non woven Geotextiles with low strength > 40 % elongation at failure, are specified by thickness and permeability. It has high in plane permeability.

- Erosion control in hydraulic problems requires a specific weight of stones over filter. For high velocity such weights are generated by Gabbions of GI wire mesh or ropes. It can create mass of tons which will not be segregated by velocity and waves of tides. They can be filled with stones and designed with filter for site conditions.

Rope gabions have advantages of placement in under water conditions or tidal waves. Both Georopes and wire-mesh mattresses are designed to suit slope protections and foundations on soft soils for structures and embankments. Fig.2 shows the laying of Roper Gabbion underwater.

Fig.2: Rope Gabbion laying under water on riverbank at Umra, Surat

- Geotubes or woven Geodrains are used for ground treatments in soft clays by special rig or mechanically drilling and placing sand stone columns.

- For seepage control polymeric membranes are adopted in combination with ground treatment and filter.

The case studies have illustrated the application made, planned and proposed. The work is empirical and site specific for the improving factor of safety in bearing, retaining, slope stability, creating lost land in flood, treating failed structures by general practice. As there is no IS code designers are guided by manufactures' of geosynthetics literature or design cell. With strong common sense with geotechnical knowledge of site problems best results can be obtained.

## 5.0 Case studies:

Through lot of R & D has flooded the literature sound theatrical base and success stories with case studies are rare leaving application design to few problems wherein conventional technology has no solution. Lot of research predictions of 2 to 3 times improved bearing capacity in sand has little field applications. The Geosynthetics and Geotechnical knowledge backed by performance of prototypes will be future needs. R & D in laboratory will not provide confidence and codes of practice.

Science 1993 authors have widely used the geosynthetics for different problems. The presentation of case studies has a limited scope of geosynthetics to civil engineering industry in design, construction, cost optimization and creating additional safety and developing R & D problems to evolve relevant IS codes.

### 5.1 Parmar Refinery Site (1993) (Barbodhan Site, Olpad, Surat):

This is tidal mud plane and first job was to provide dykes to demark tidal creek. The rest of land also required the ground treatment for land fill, roads and low rise structures. Heavy plants are on piles.

The dykes as shown in Fig. 3 proposed using Netlon Geogrids, Geofilter (GPB 127), Geobags of polypropylene (PP) were used in combination with soil stabilization with lime CaO, CaOH. This project was latter abandoned.

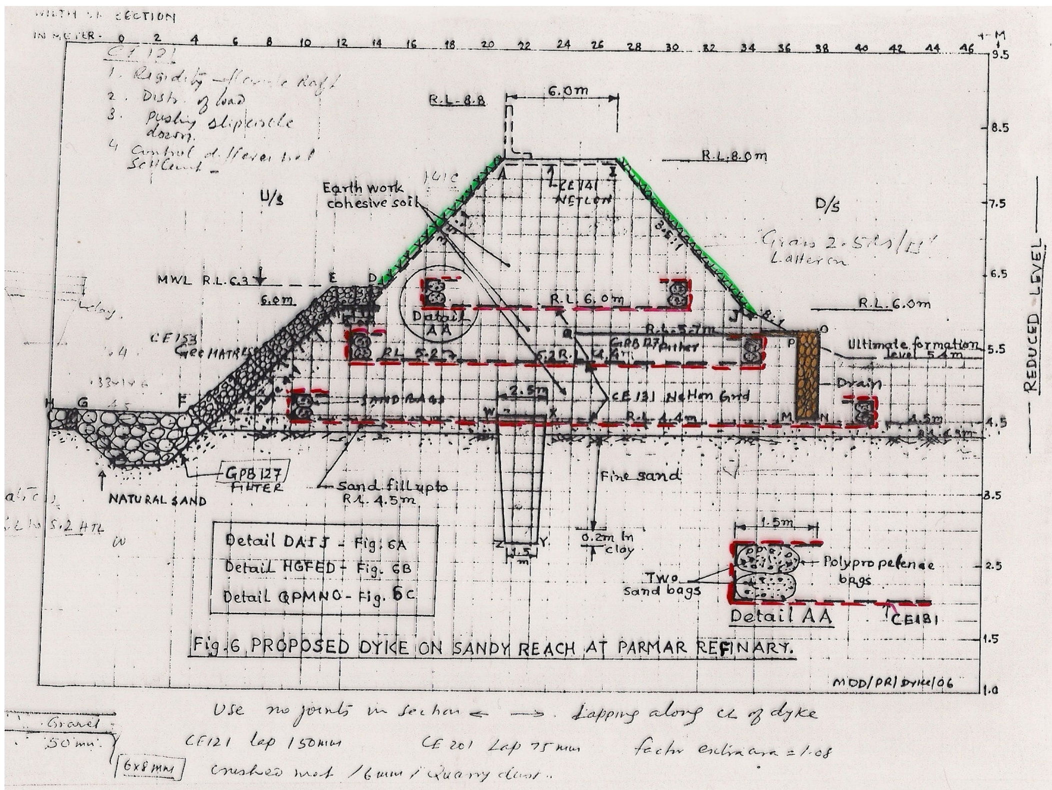


Fig. 3: Sketch showing proposed treatment for Parmar Refinery Site (1993)

### 5.2 Scour hole and scour upstream of Singapore weir (Source of water supply to surat) (1994):

Sand mining, floods, hydraulic dredging of sand, developed large pocket, a deep hole & scour u/s of apron of weir. This could in low reservoir level intrude salinity from the sand foundations of weir. Emergency repairs were executed using rope Gabbions, placed by winch and pontoon under 3 to 4 m of water using Naval divers. Geofilter and Gabbions placement is shown in Fig. 4, 5, 6.

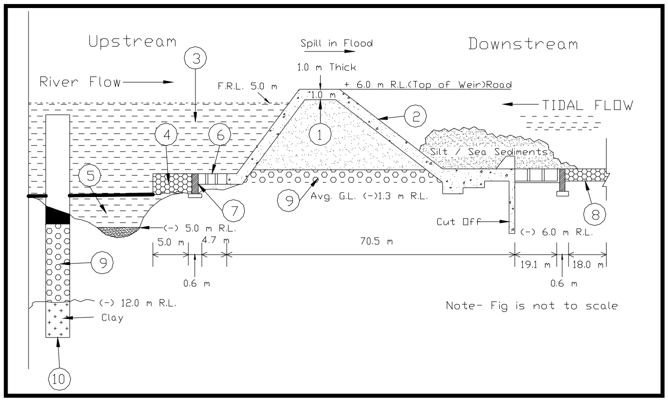


Fig. 4: Cross Section of Weir Bays-Showing probability of Piping (weir Surat) (1994)

Legends:

(1) Sand fill, (2) C.C. weir floor & glacis, (3) Sweet water Pond, (4) Original loose stone Apron of stones weighing min. 40 Kg & size 300 mm upstream, (5) June '2000 Scour Pocket, (6) P.C.C. block, (7) R.C.C. toe wall, (8) Loose stone Apron, (9) Sand & Gravel (Bed Material), (10) Bore.

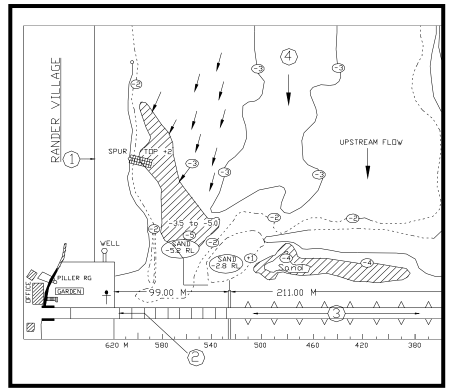


Fig. 5: Scour Pockets – Channel Formed At Upstream Of Weir, Surat.

Legends:

(1) Flood protection wall / Embankment,
(2) Sluice Gate,
(3) Weir Top,
(4) Channel Formed by sand Mining in Upstream

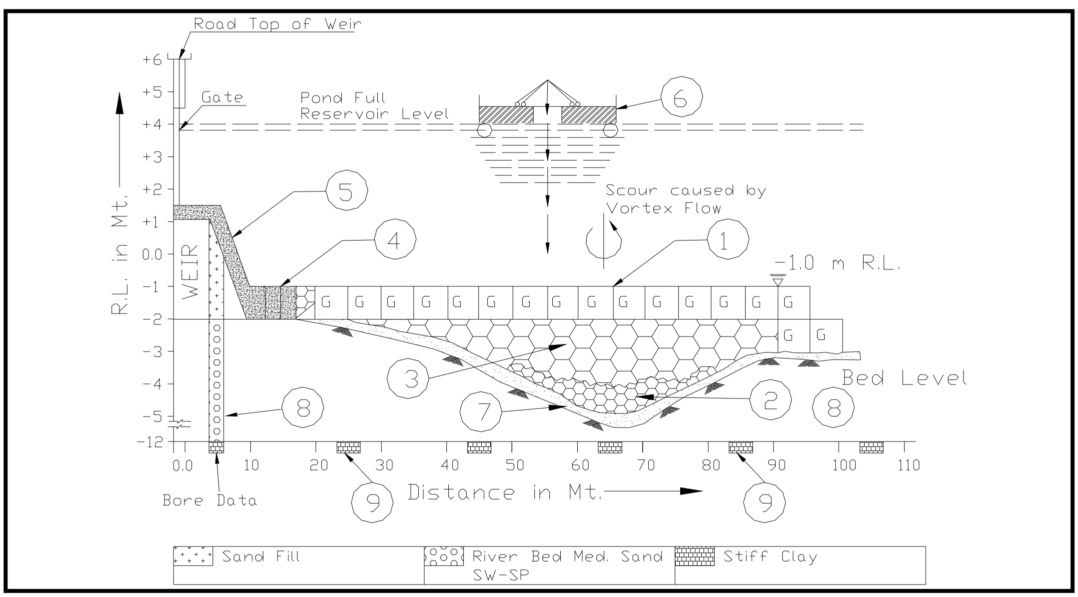


Fig. 6: Typical Cross-Section of Upstream Scour Hole Indicating, (a) Upstream concrete Top & Apron, (b) Proposed repairs

Legends:

(1) Proposed Rope Gabions (G), (2) Stitched Geotextile filter bags filled with sand laid under water, (3) Dumped stone fill dropped from Pontoon, (4) Launching Apron (C.C. blocks & stone riprap),(5) C.C. weir Floor, (6) Pontoon, (7) Silt (1.0 to 2.0 m deep), (8) Medium sand, (9) Stiff clay

## 5.3 Recreating lost land by scour of floods (Party Plot at Umra), Alternative to Spur to protect LB of Tapi at Singanpore Breakwater (1998-1999).

The flood eroded left bank & cut the land by channel 8 m deep. This destabilized Left bank of Singanpore village. Considering alternative & site specific flow of tidal water break water was planned using rope Gabbions with Geofilter U/S & D/S. The plates will show the problem of construction in low tides. Initially link to island formed a silt trap for tidal mud allowing water to seep back. The entire land was recreated to RL (+) 3.0 to 3.5 m by 2002.

The Gabbions sunk by 1 m total depth as foundations.

Typical techniques of approaching tidal river for land fill by spurs with dyke (parallel to bank) was used for stage filling of soli wastes. Once the tidal level was crossed work, was conventional. Fig. 7, 8, 9, 10 shows the treatment provided at site.

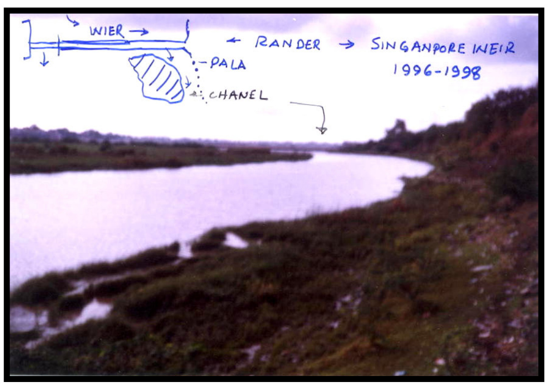


Fig. 7: 1996-98 Flood-Scoured deep cut on left Bank D/S of weir. Island, Channel, Bank with flood embankments. Danger for Pala at Bharimata, piping under Pala.

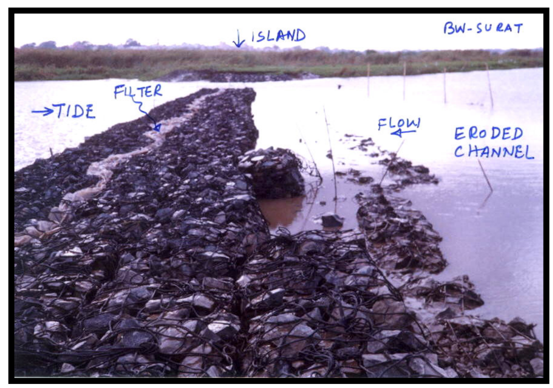


Fig. 8: Laying of Gabbions, Filter in stages in tidal zone.

Fig. 9: Closer of Break Water to island with tide water


Fig.10: Silting on Weir & Island side (2000).

## 5.4 BAPS Temple, Tithal, Valsad (2000):

The sea wave erosion eroded 20 - 30 m of bank near temple as shown in Fig. 11 & Fig. 12 endangering temple foundations. Wire rope Gabbions, hand placed stones and use of Geofilter, planned, executed and maintained as shown in Fig. 13, 14, 15, 16 explain success story.

The hydraulic alignment & cut off gabions provided good sand beach at site.

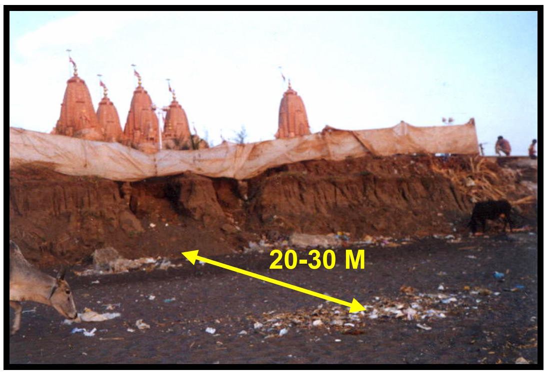


Fig. 11: 20 - 30 m Erosion on Swaminarayan Temple Plot by Tide (1999-2000)


Fig. 12: Eroded sandy slope 4 m to 5m high.

Fig. 13: Tide Invades Construction Two Times – Work Completed in 100 Days

Fig. 14: Final layout, backfill with Sand at BAPS, Tithal.

Fig. 15: Final finished level at BAPS, Tithal in year 2000

Fig. 16: Sea bank profile in October 2009 at BAPS Temple, Tithal.

### 5.5 Gas pipelines:

**Surat in Tapti - 2005, GALE at Kaveri River - Bharuch, West to East Reliance gas pipeline crossing of Tapti river (Abrama).**

**Tapti river pipeline Emergency work:**

The pressure mains of gas, for safety, requires loading on the top 2 X pressure. Loss cover on top by erosion had to be created on emergency basis for Surat & GALE line at Kaveri River. Abrama project was only designed. Fig. 17, 18, 19, 20 shows adoption of Geosynthetics for erosion, surcharge and hydraulics of river.


Fig. 17: Gas Pipeline Bed Erosion, Pal, Surat.


Fig. 18: Erosion protection treatment by Gabion & Geo-filer: Geo-synthetics.


Fig. 19: Protection work in progress at Gas pipeline, Surat.


Fig. 20: Finalized profile protection against erosion at Surat.

**<u>HBJ pipe (Gas) under mined, Kaveri river , Bharuch (GAIL) (2000).</u>**

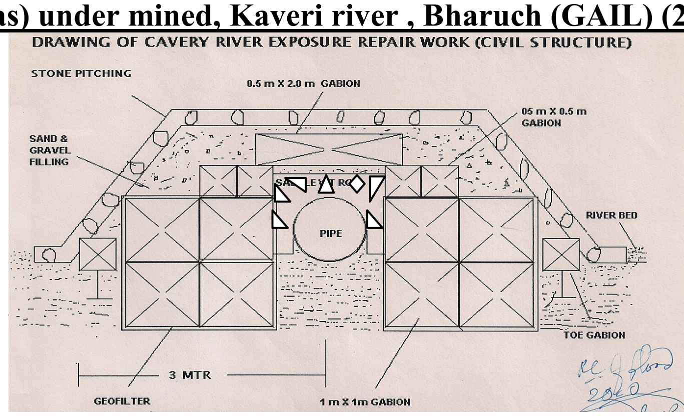


Fig. 21: Drawing showing completed scour treatment at the right bank of Kaveri River, Bharuch. Left bank was protected by wiremesh gabbions 10 years ago.

## Reliance Pipeline Bank Protection (2007)

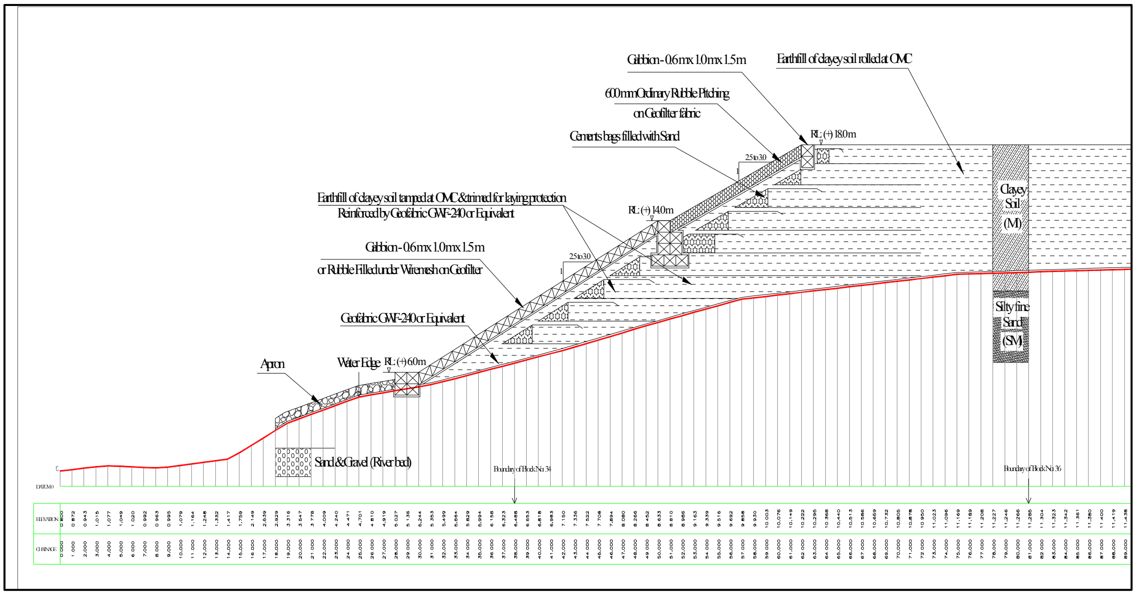


Fig. 22: Bank protection over proposed pipeline at Tapti River, Abrama, Reliance West to East Gas pipeline

### 5.6 Emergency under water repair by apron (2000) for the D/S retaining wall (RB) of Singanpore weir.

The scour for high retaining return wall of weir was checked by apron of Gabbions as seen in Fig. 23, 24, 25, 26.

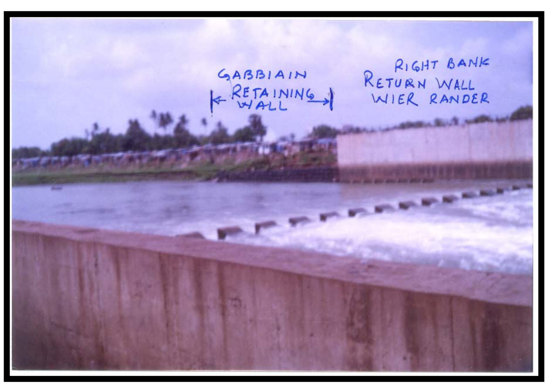


Fig. 23: Weir Return Wall, Weir Under Sluice & Protection Gabbion Wall Protection-view (1998).

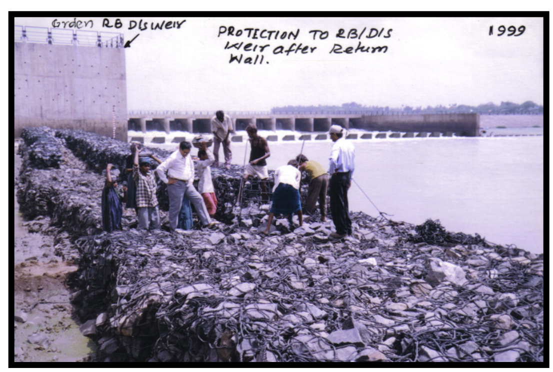


Fig. 24: Right bank protection work under construction


Fig. 25: Construction phase with free tide movement.

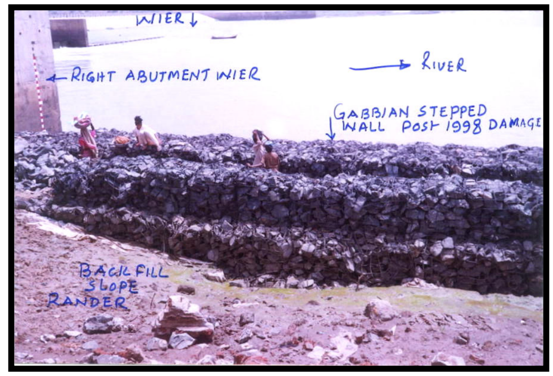


Fig. 26: Stepped Gabbions with backfill, slope above

## 5.7 Foundation of Structures:

The use of geotextile as separator, filter and availing tensile reinforcing is illustrated by typical structures.

**ABRAR Apartment at Surat (2003)**

The ABRAR apartment complex (2003) Fig. 27 is typical illustration. Fig. 28 shows excavation in loose silt and fine sand to more than 3 m. Laying Geofilter in total area, placing & compacting excavated soil in layers as shown in Fig. 29 to prepare base for foundations is example to provide net Safe Bearing Capacity of 30 T/m$^2$ and permissible differential settlement 25 mm. The structure is on bank of river Tapti.

Fig. 27: Elevation of ABRAR apartment.

Fig. 28: Excavation of Creek zone at ABRAR apartment.

Fig. 29: Providing fabric & fill & compacting in layers

**Surat International Exhibition & Convention Centre at Sarsana, Surat (2009)**
Finished structure of South Gujarat Chamber of Commerce & Industry's exhibition pavilion SIECC at Sarsana shown by Fig. 30 & Fig. 31 had seepage and loose foundation soil which is incapable to take design stress of 20 T/m$^2$. Structural designer, contractor were convinced to use high tensile Geofilter with sand fill as shown in Fig. 32, 33, 34, 35.


Fig. 30: Finished structure of SIECC Sarsana at completion

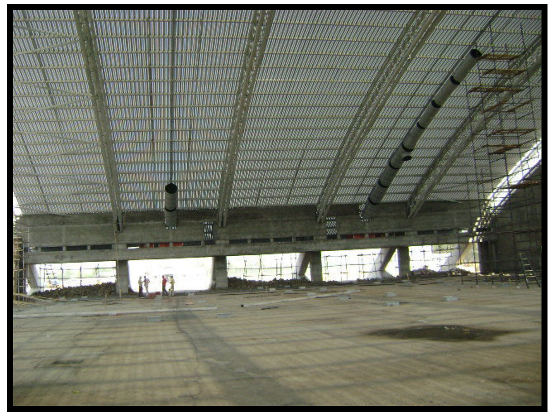

Fig. 31: Inside view of SIECC structure near completion.

Fig. 32: Ground water seepage at foundation level after excavation at SIECC Sarsana.

Fig. 33: Laying of Geotextile at foundation level for SIECC.

Fig. 34: Proving Sand layer above Geotextile at SIECC.

Fig. 35: Foundation above ground level on treated soil at SIECC.

**BAPS Akshardham at Delhi (2000)**

The use of Gabbions, mattresses, stone fill in layers with filter formed foundations for world monument of BAPS Akshardham at Delhi to control probable liquefaction & differential settlement (Ref. 1) is shown in Fig 36.

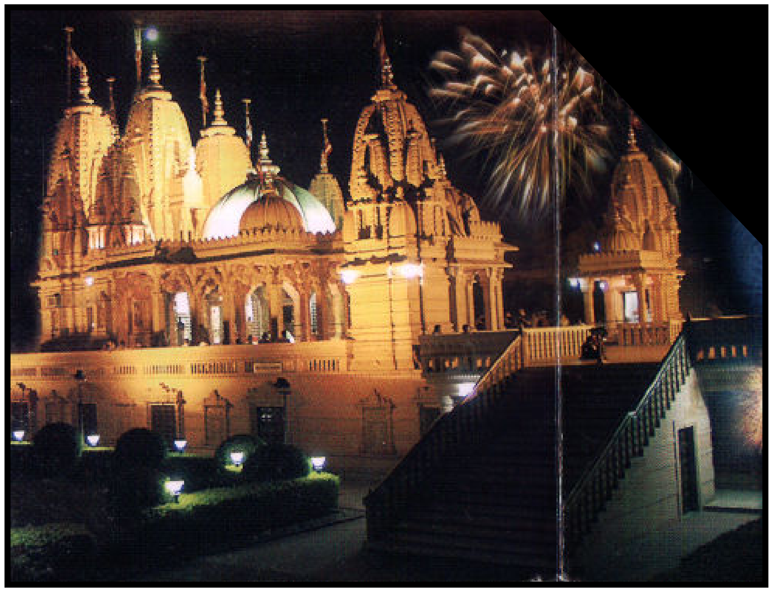

Fig. 36: Finished structure of BAPS Akshardham at Delhi.

## 5.8 Geosynthetics application to other civil engg projects:

The geosynthetics technology has been offered for RE walls, ponds to control seepage, river bank protection works, foundation treatment to drain pore water pressure, pavement etc. they are not covered here.

**Acknowledgement:**

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