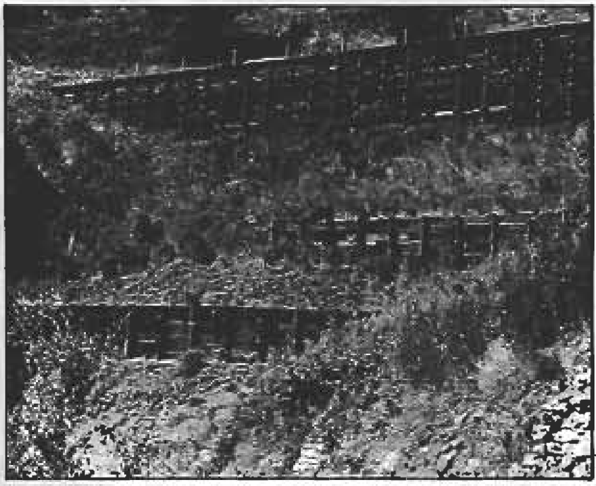
ALTERNATIVE EARTH RETAINING SYSTEMS IN CALIFORNIA HIGHWAY PRACTICE

June 1986

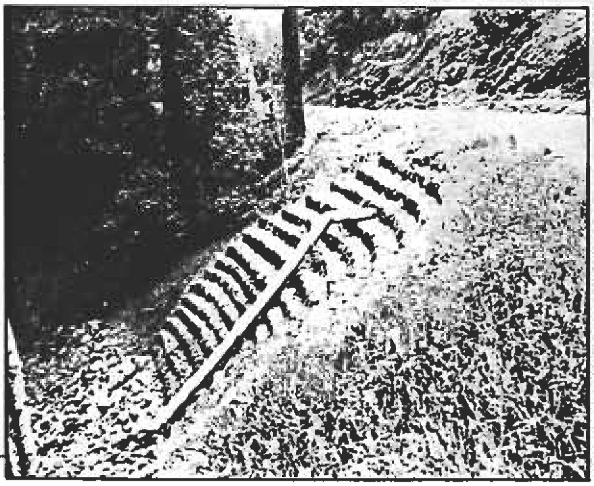
1



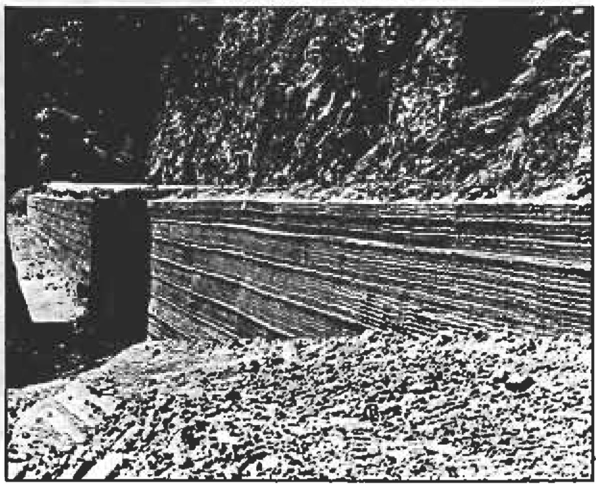
2

3

4



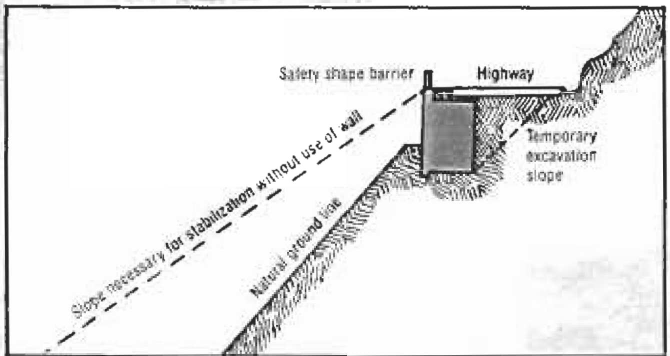
5



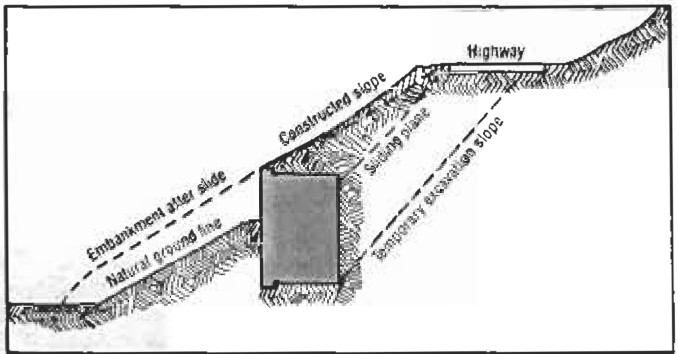
6

1. Mechanically Stabilized Embankment (MSE) 2. CALTRANS T-A-T, Tire Anchored Timber Wall
3. CALTRANS Salvaged Guardrail Wall 4. Earthstone Wall 5. Tensar Embankment 6. Hilfiker Welded Wire Wall

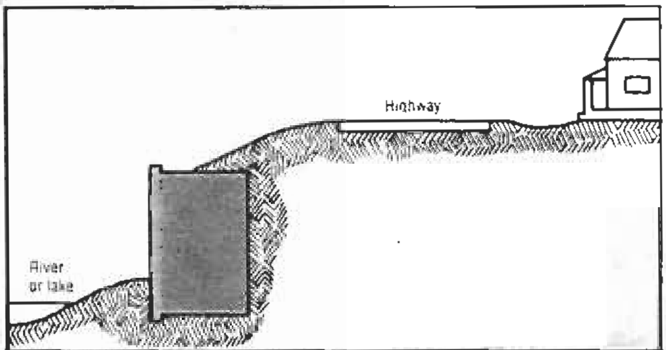
TYPICAL WALL APPLICATIONS



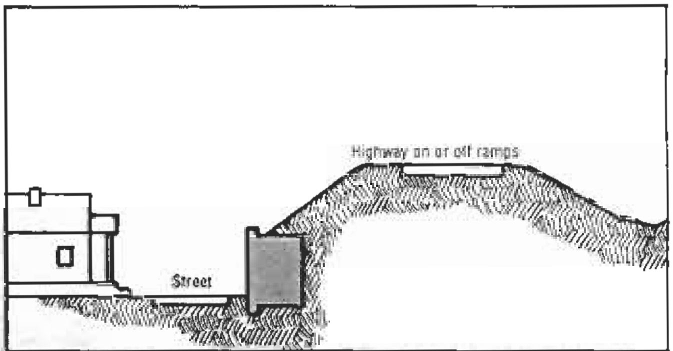
Eliminating excessive fills with use of walls.



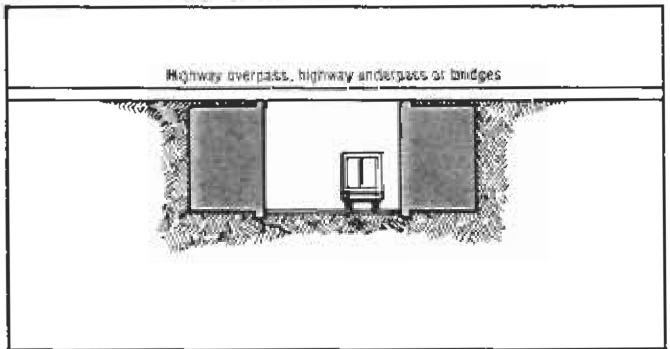
Slide repair.



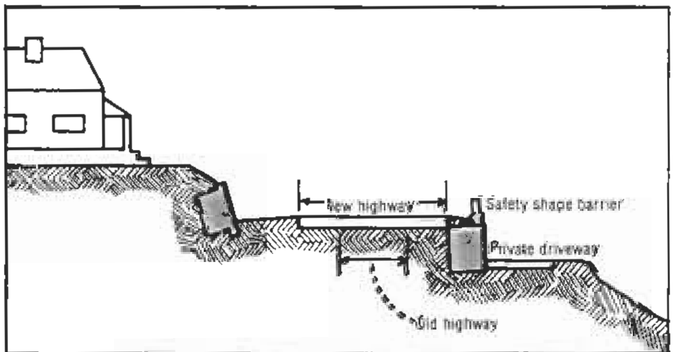
Preventing encroachment of highway embankments into river.



Reducing right-of-way requirements, grade separations.



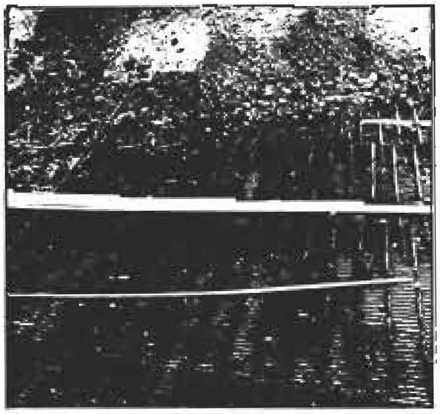
Abutments for structures.



Road widening with minimal encroachment.

Mechanically Stabilized Embankment, bar mats in position.

Recycling of non-biodegradable tire **sidewalls** in construction of "Tire **Anchored** Timber Wall."



Tensar grids, in corrosive environments, are made of polymer-type materials.

INVESTIGATIVE GUIDELINES

Every retaining wall location should be considered for an Earth Reinforcing System and as early as possible in the design phase.

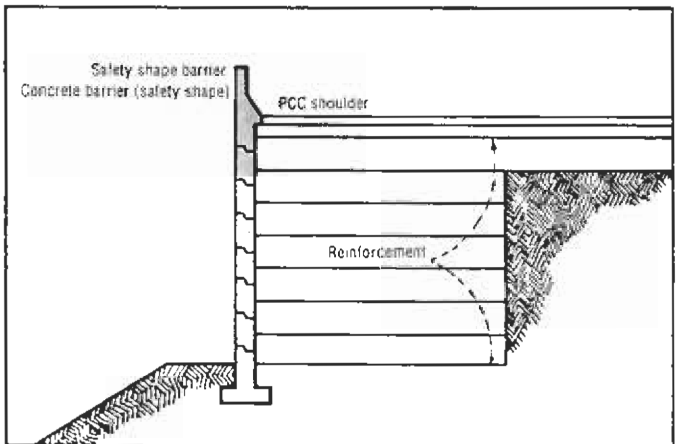
The following table lists typical investigative requirements and notes who performs them.

1) Tentative wall lay-out line (LOL):	District or Office of Structures Design (OSD)
2) Tentative grade line	District or OSD
3) Site topography:	District
4) Site geology:	District or Translab
5) Groundwater (including streams):	District or Translab
6) Loading on wall; e.g. traffic:	District or OSD
7) Soil strength parameters:	Translab
8) Construction or traffic constraint:	District
9) Nearby culverts, buildings, etc.:	District or OSD
10) Horizontal Component of earthquake acceleration:	Translab or OSD
11) Corrosion Parameters:	Translab

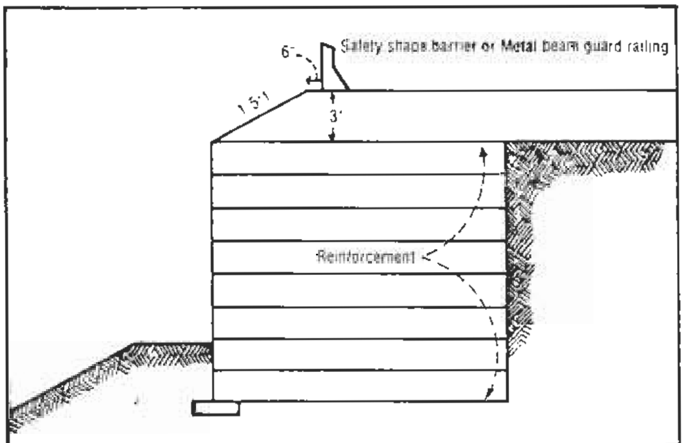
Additionally, for stabilization of landslides information about the failure plane and type of failure (e.g. rotational) would be needed. Excavation at the toe of a slide or even of the whole slide mass is sometimes dangerous, costly and self-defeating. Working with the forces of nature by leaving the slide mass in place and realigning the roadway should be considered.

(Due to legal agreement with The Reinforced Earth Company, until August, 1989, that company must be given the opportunity to submit a wall design for any site where the CALTRANS Mechanically Stabilized Embankment (MSE) WALL SYSTEM IS SPECIFIED. To comply with this agreement, a two month lead is appropriate before PS & E.)

TYPICAL GUARD RAIL INSTALLATION



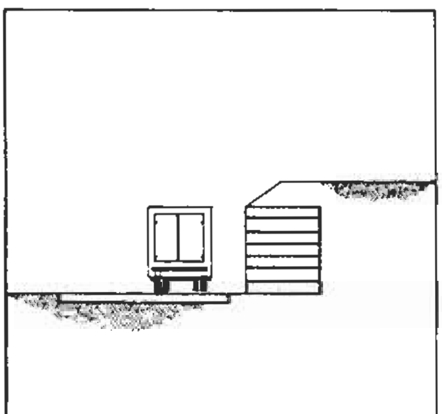
All PCC panel walls



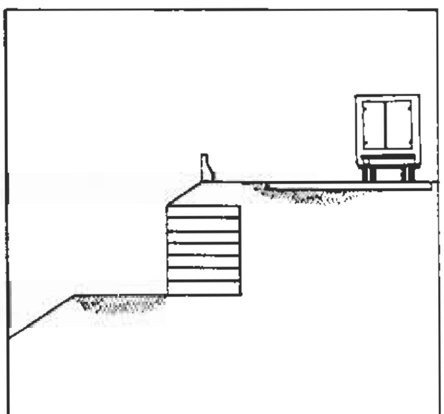
All other wall types

TYPICAL WIDTH TO HEIGHT RATIOS

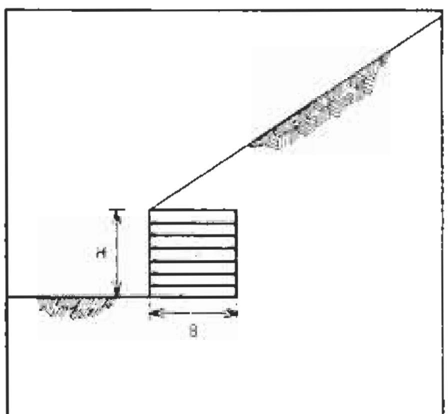
(For CALTRANS MSE, TAT and Salvage Guard Rail Wall)



Case 1 B/H = 0.6 – 0.7



Case 2 B/H = 0.6 – 0.8



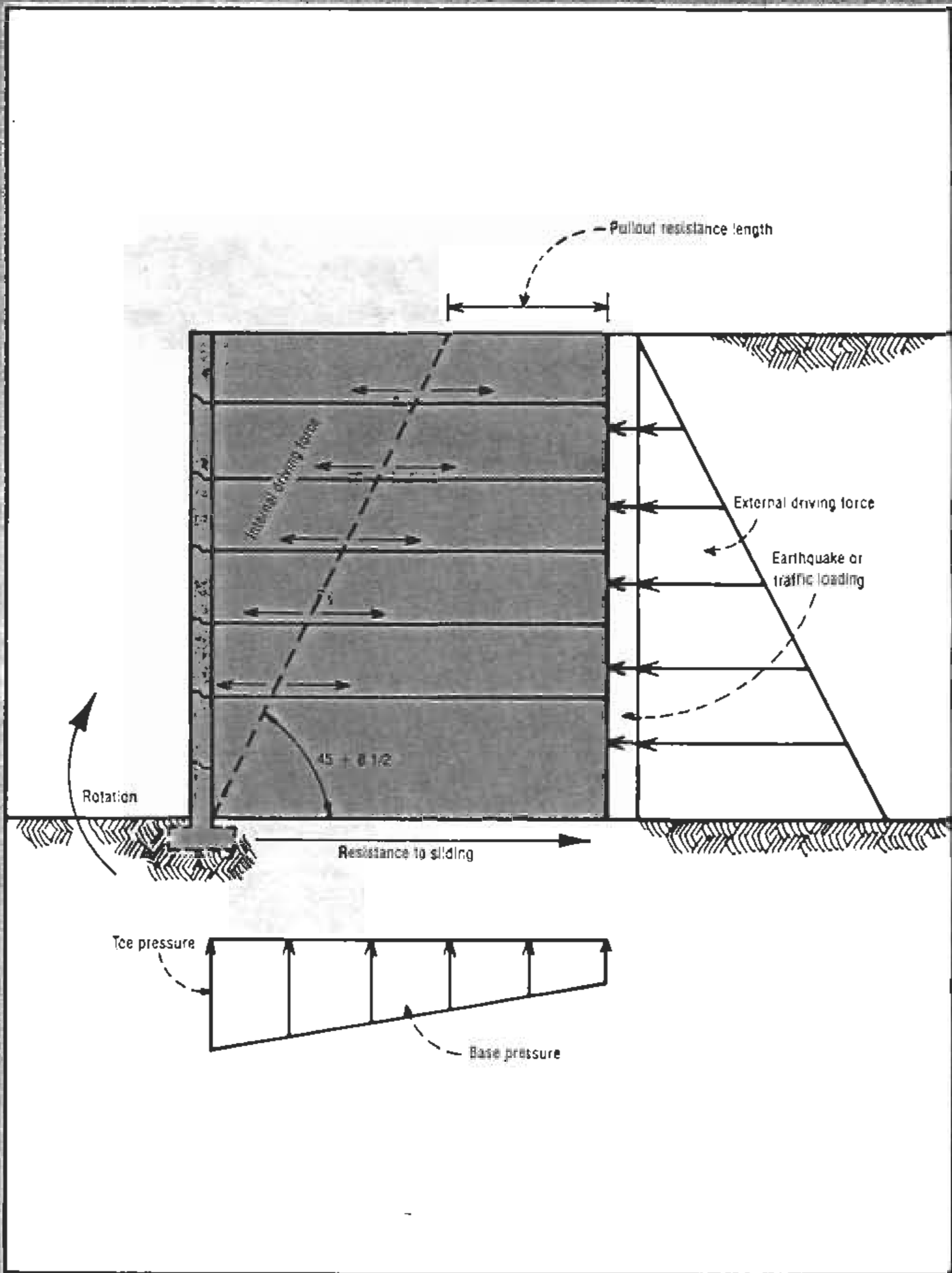
Case 3 B/H = 0.7 – 1.0 (stable slope), B/H ⟩ 1.0 (unstable slope)

STABILITY

External Stability. Any wall system must be designed to resist failure by sliding along its base, bearing, and overturning about its toe. Factors of safety of 1.5 with respect to sliding and 2.0 with respect to bearing and overturning are typically used. Included as the driving forces are the active lateral earth pressure, hydrostatic pressure, and any lateral forces due to earthquake or traffic loading.

Internal Stability. All reinforced wall systems must also maintain a factor of safety of at least 2 with respect to pullout of the reinforcing elements and each level of reinforcement must be examined. Only that portion of the element beyond the assumed failure plane will act to resist pullout.

System Behavior. Proper design will result in structures as strong or in certain applications, stronger, than conventional designs especially for wall heights greater than 20 feet. Reinforcement acts as a tension element and as such resists soil dilation leading to increased shear resistance. The non-rigidness of the reinforced soil block provides flexibility to tolerate large settlements and seismic motions. Since the reinforcement absorbs much of the horizontal soil pressure, wall pressures are significantly lower than walls without reinforced backfills.



CORROSION

Corrosion of Metal Elements in Soil. Translab has developed an *interim* equation to predict the life expectancy of metal reinforcing elements buried in soil. Input to the equation include member diameter (or width and thickness) amount of galvanization, and soil PH and resistivity, and the soils soluble salt content. Bag samples (30#) can be sent to the Lab for determination of the soil parameters.

Galvanized (or ungalvanized) reinforcing members are designed to not exceed 55% of the steel's yield stress in 50 years (working stress design). By slight increases in member size and/or by using select granular backfills, engineer can achieve life spans way beyond useful life of facility.

COMPARISON OF ALTERNATIVES

Type of Wall	Cost Saving Potential	Aesthetics	Ability to Tolerate Settlement	Require Quality Backfill	Earthquake Resistance	Facing Material	Require Additional Field Construction Time	Maximum Reasonable Wall ht., ft (vert. wall)	Corrosion Resistance	Soil Reinforcement Type
R.C. Cantilever Wall (spread foundation)	F	G	P	YES	E-G	concrete	NO	30	E	—
R.C. Cantilever Wall (pile foundation)	F	G	P	YES	E-G	concrete	YES	30	E	—
Permanent Tieback	P	G-F	P	NO	G-F	wood concrete	YES	40	G	steel
Bin or Crib Wall	G	F	F	YES	G	metal concrete	NO	40	E-G	—
CALTRANS MSE*	E-G	E	G	NO	E	wood concrete	NO	50	F	steel
Reinforced Earth	E-G	E	G	YES	E	concrete	NO	80	G-F	steel
Hilfiker RSE, VSL	E-G	E	G	NO	E	concrete	NO	50	F	steel
Welded Wire Wall	E	P	E	NO	E	wire	NO	30	F-P	steel
CALTRANS T-A-T**	E-G	E	G	NO	E-G	timber	NO	30	G	steel
CALTRANS Salvage Guardrail Wall	E-G	G-F	G	NO	E-G	metal concrete	NO	30	G	steel
Double Wall	E	G-F	F	NO	P	concrete	NO	20	E	—
Earthstone/Loffelstein***	E	E-G	G-F	YES	P	concrete	NO	—	E	fabric (optional)
Gabion	G	P	G	YES	G	wire	NO	12	G-F	steel
Fabric Wall	E	P	E	NO	E	gunite tar emulsion	NO	—	E	geo-textile
Tensar Wall	E-G	F-P	E	NO	E	concrete plastic	NO	—	E	plastic

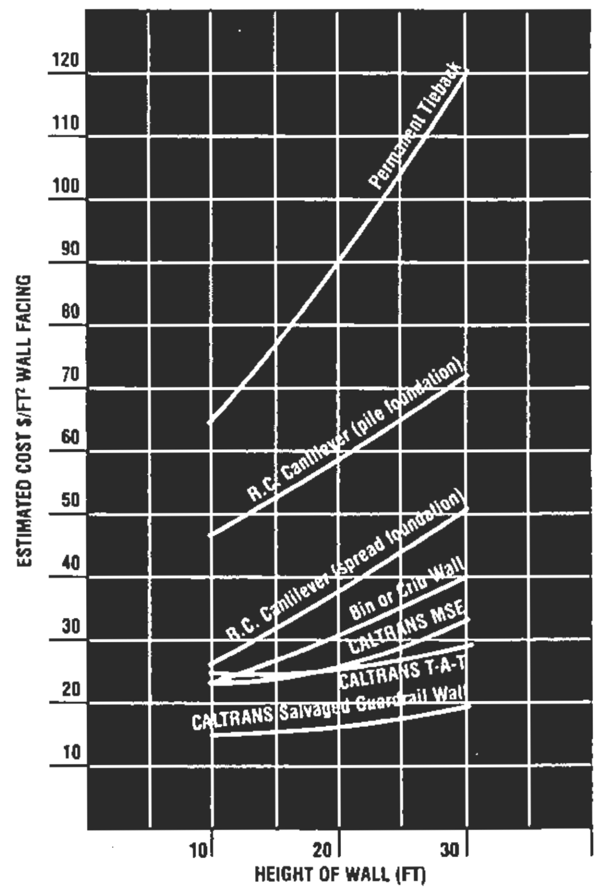
*Mechanically Stabilized Earth **Tire Anchored Timber Wall ***G if Backfill is Fabric Reinforced Rate: E = Excellent G = Good F = Fair P = Poor Limitation: Yes No

COMPARISON OF 1985 CONSTRUCTION COSTS

($ per square foot of wall facing)

Height of Wall (ft.)	10′	20′	30′
R.C. Cantilever Wall (spread foundation)	$26	$37	$ 50
R.C. Cantilever Wall (pile foundation)	46	58	72
Permanent Tieback	65	90	120
Bin or Crib Wall	23	32	40
CALTRANS MSE (with low quality backfill)*	23	26	33
Reinforced Earth	25	28	35
Hilfiker RSE, VSL	25	28	35
Welded Wire Wall	13	15	18
CALTRANS T-A-T**	24	26	28
CALTRANS Salvage Guardrail Wall	15	17	19
Double Wall	14	17	22
Earthstone***	8	10	14
Gabion	25	33	55
Fabric Wall	10	12	14
Tensar Wall	17	20	25
Loffelstein***	12	14	18

*Mechanically Stabilized Earth (MSE)
**Tire Anchored Timber Wall (T-A-T)
***Walls Are Small PCC Block Facing Elements. If backfill is fabric reinforced add $5/sq. ft.



PARTIAL SUMMARY OF CONSTRUCTED ALTERNATIVE EARTH RETAINING SYSTEMS

Reinforced Earth (RE) Wall

*Los Angeles, L.A. Co.	Hwy 39	1972
*Dunsmuir, Siskiyou Co.	I-5	1976

Highway 39 was the first Reinforced Earth Wall constructed in the United States. Maximum height is 55 feet. This project utilized steel facing elements and was designed to stabilize a slide in steep terrain. The wall performed excellently. Other slides in non-stabilized areas eventually caused closure of the highway.

Mechanically Stabilized Embankment (MSE)

*Dunsmuir, Siskiyou Co.	I-5	1976
*Delhi, Merced Co. (wood facing)	Hwy 99	1979
*Baxter, Placer Co.	I-80	1982

MSE was developed by CALTRANS in 1973. The basic modification used bar-mats as soil reinforcement to provide additional pullout resistance over the original smooth steel strips used in Reinforced Earth. The increased pullout resistance (by a factor of 6) permitted the use of local low quality material as backfill. The first full-scale experimental MSE was constructed in 1976 along I-5 at Dunsmuir and the latest successful MSE was completed on I-80 at Baxter in 1982.

Caltrans Tire Anchored Timber Wall (TAT)

*Mono Co.	Hwy 203	1981
Santa Cruz Co.	Hwy 1	1983
Sausalito, Marin Co.	Hwy 101	1983
San Mateo Co.	Hwy 92	1984
San Mateo Co.	Hwy 114	1984
Marin Co.	Hwy 101	1985

The three-level wall in Sausalito used salvaged automobile tire sidewalls with steel anchor rods as reinforcement to stabilize a hillside downslope from a state highway. In addition to a possible loss of the roadway, homes were in the potential slide area. Therefore, this site demanded critical and immediate attention. Cut-off drainage trenches were used to keep the hill as free of groundwater as possible. New and salvaged railroad ties were used as the facing on the wall; the treated timber is expected to have a 50 year life.

CALTRANS/Salvaged Guardrail Wall

*Thousand Oaks, Ventura Co.	Hwy 101	1981

This wall was constructed to accomplish a highway widening. Salvaged and new guardrails were used as the facing members. Low quality backfill can be used with these walls.

Hilfiker Welded Wire Wall

Blue Lakes, Lake Co.	Hwy 20	1982
Helena, Trinity Co.	Hwy 299	1983

Galvanized welded wire fabric is used for both the facing and internal reinforcement in this wall system. The facing can be left exposed with vegetation eventually growing, or gunited. Maximum wall height was 22 feet at Blue Lakes project on Highway 20.

Earthstone Wall

Bakersfield, Kern Co.	Hwy 178	1984

Basically a gravity wall system. The wall is placed on a concrete leveling pad. Free-draining material must be placed immediately behind the wall facing and allowed to drain under the pad, although some drainage can occur through wall seams. The wall facing can be exposed to stream flow with no ill effects. Fabric reinforced backfill needs to be used in conjunction with these blocks to provide permanent backfill stability.

Fabric Wall

Plumas Co.	Hwy 70	1983

Woven or non-woven fabrics can be used to form a reinforced soil mass. To prevent most fabric UV deterioration, walls are generally coated with gunite or asphalt emulsion.

Tensar Wall

*La Honda, San Mateo Co.	Hwy 84	1985

Tensar, a net-like (geogrid) product from the Netlon Company, provides internal reinforcement of the soil mass in much the same fashion as MSE. Some geogrids are made of polymer-type materials which are extremely stable in highly corrosive environments. Facing can be seeded or covered with gunite, depending on needs and/or UV resistance.

NOTICE

The contents of this brochure reflect the views of the Office of Transportation Laboratory which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation or endorsement.

*Research reports available upon request.

Study provided by: Geotechnical Branch ▪ Transportation Laboratory ▪ 5900 Folsom Blvd. ▪ Sacramento, CA 95819 ▪ (916) 739-2364

DESIGN: CALTRANS GRAPHIC SERVICES 916/445-6675 TRANSLAB 916/739-2491