C.R. Coll. Int. Renforcement des Sols. Paris 1979.

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Application of reinforced earth in highways throughout the United States

Utilisation de la terre armée sur autoroutes aux U.S.A.

En 1974, après plusieurs années d'observations sur des ouvrages experimentaux servant de tests, l'Administration Fédérale des Autoroutes a approuvé le principe de l'utilisation de la terre armée dans les ouvrages de soutènement des projets autoroutiers.

Plus de 200 ouvrages sont ainsi construits dans 26 des 50 Etats de l'Union. Ils ont pour but soit l'amélioration du tracé des nouvelles autoroutes, soit l'élargissement des chaussées des anciennes, soit leur protection contre des éboulements.
Quelques exemples sont décrits.
L'amélioration et le développement du réseau autoroutier des Etats Unis permet une utilisation intensive de la terre armée, matériau économique et de qualités techniques et architecturales élevées.
Les spécifications de l'Administration et de la Société La Terre Armée sont également analysées.

INTRODUCTION

Reinforced Earth was first introduced in the United States in 1969. Convinced of its potential advantages, in 1970 the Federal Highway Administration initiated a number of demonstration projects. In 1974, as a result of experimental testing and experience acquired during the demonstration program, Reinforced Earth was removed from experimental status. This change in status constituted an approval of Reinforced Earth as an acceptable standard highway construction process for earth force retention. Results of the demonstration program were reported in the Federal Highway Administration publication "Reinforced Earth Construction," dated April 1975.

U.S. CONTRACTURAL PROCEDURES

Generally construction projects are opened to competitive bidding and the Reinforced Earth Company, serving as a subcontractor, supplies all prefabricated components and technical assistance prior to and during construction.

The decision to use Reinforced Earth in lieu of conventional retaining techniques is based on economics, technical superiority, or esthics. If the decision is based on economics, designs for both Reinforced Earth and a conventional alternate are generally included in the plans and bid separately. If the decision is based on considerations other than economics, a certification is generally supplied stating that no equally suitable alternate exists for this project. Relatively few construction problems have been detected on Reinforced Earth projects. Those which have occurred have generally been the result of a lack of understanding or enforcement of the construction specifications. These problems generally are evident only with the first projects constructed by an agency.

SPECIFICATIONS

Within the United States, there are no national specifications for design and construction of Reinforced Earth structures. In 1974, Reinforced Earth was included in "Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects" (FP-74). These specifications are used only for projects constructed by the Federal Government to assure quality control during construction. The great majority of federally funded projects are designed and constructed by individual State agencies. While some agencies do use the Federal specification as a guideline, the responsibility for specification development rests with the contracting agency for each project. The Reinforced Earth specification contained within the Federal Specifications was derived primarily from the French specification and placed the following requirements on backfill material used within the structural volume:

Sieve Size	Percent Passing
10 inches	100
4 inches	100-75
No. 200	0-15

$\phi > 25^\circ$ (As determined by standard triaxial or direct shear testing methods)

Based on experience and the results of theoretical and applied research, the maximum percent passing the No. 200 sieve will be increased to 25 in the Federal construction specification (FP-79) to be issued in January 1979. Backfill material must be non-plastic (PI < 6) however, a minimum shear strength value is not specified. Material not meeting these criteria may be used only if approved by the engineer.

TYPICAL APPLICATIONS

A majority of the initial Reinforced Earth projects involved correction of difficult and pressing problems, such as, failed embankments and cut slopes. As a result of successful application in these initial projects, the system has gained acceptance and is now used routinely in the design of new facilities. To date, over 200 transportation related structures have been completed in 26 of the 50 States; these include highway, railway and mass transit facilities. Applications have been widely diversified and include: (12) slide corrections, (38) bridge abutments, (9) marine walls, (3) Reinforced Earth slabs, and (130) retaining walls for cuts and fills.

The following examples demonstrate three of the more recent typical applications of Reinforced Earth.

Bridge Abutment - The first Reinforced Earth project constructed by the Alabama Highway Department was a bridge abutment in the downtown area of Huntsville, Alabama. Designing the grade separation at this major intersection of the Memorial Parkway involved some difficult problems. The 100,000 vehicles per day traffic carried by the intersection had to be maintained during construction. Previous experience with conventional cantilever retaining walls in this area indicated as long as 12 months would be required for wall construction. Considerably less time would be required for Reinforced Earth, which was eventually chosen for this reason.

Construction of a Reinforced Earth abutment could eliminate a 65 foot section of the dual bridges. It was decided however, that the predicted three inches of subsurface settlement was excessive for the continuous steel girder design. In order to tolerate this settlement, a simple span was placed adjacent to the termination of the continuous girders. This resulted in a net savings of \$35,000 through the elimination of 30 feet of structure. An additional \$200,000 was saved by selection of Reinforced Earth as opposed to a conventional retaining structure.

The 14,953 square foot wall was constructed in 9 weeks for an average erection rate of 1,650 square feet per week. A view of the completed structure is shown in Figure 1. Figures 2 and 3 show typical cross sections.

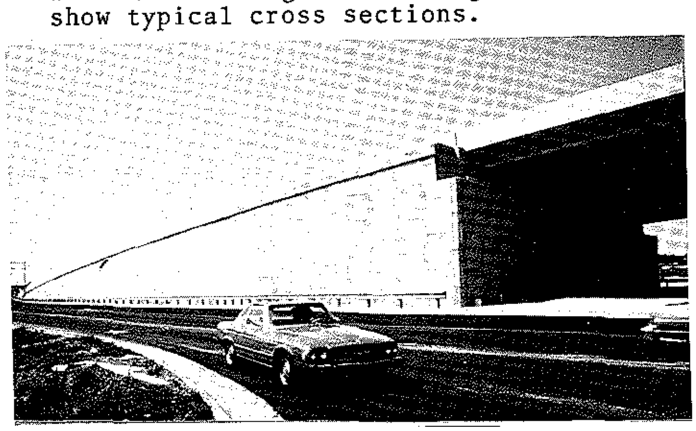

Figure 1. Completed Project Huntsville, Alabama

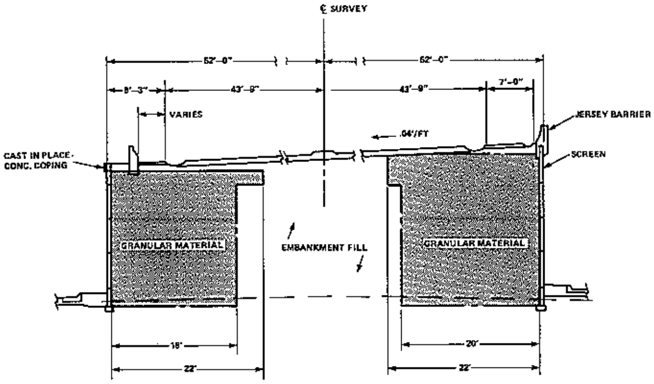

Figure 2. Section Thru Walls - Huntsville, Alabama

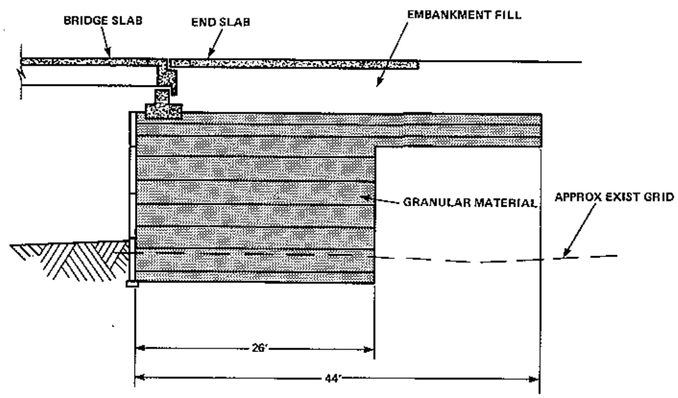

Figure 3. Section Thru Abutment - Huntsville, Alabama

Existing Highway Widening-widening and upgrading existing U.S. 70 and I-40 provides an excellent example of Reinforced Earth construction in mountainous terrain. This project, which is situated in the Blue Ridge mountain area of North Carolina, involved construction of Reinforced Earth walls at four locations. These walls had a maximum height of 50 feet and a total length of 2300 linear feet.

Since existing slopes were as steep as one on one and only marginally stable at certain locations, special treatment was necessary to construct the required fill sections. Unstable foundation conditions eliminated the possibility of economically constructing a bridge over the area. Reinforced concrete walls, at an estimated cost of $1.5 million, were also considered a possible alternate. Undesirable aspects of this approach were: First, the massive wall sections would have to be placed on soils having questionable support properties and second the existing roadway grade would be indangered during excavation and wall construction phases of the project. A third alternate, which involved shifting the highway alignment, required removal of 2.5 million cubic yards of material, at a cost of $4.7 million. The estimated cost of the Reinforced Earth alternate was $1.3 million. In addition to being economical, the time required for construction was considerably less than that required for conventional retaining walls. This resulted in a reduced hazard to the travelling public, since traffic had to be maintained during construction. The 67,396 square feet of wall was constructed in 7 months, for an average erection rate of 2,250 square feet per week. A view of the completed wall and typical cross section is provided in Figures 4 and 5 respectively.

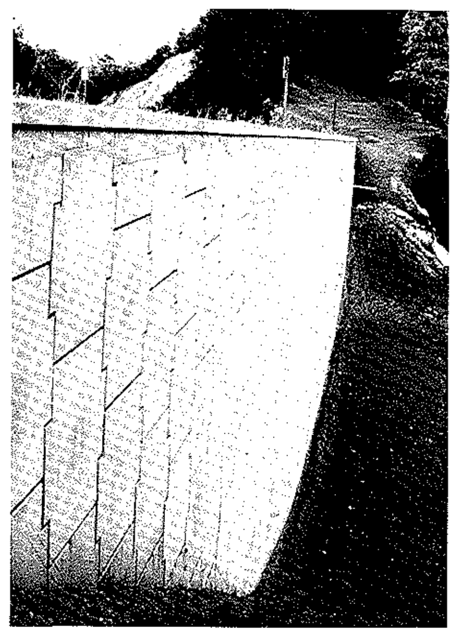

Figure 4. Completed Wall - I-40 - North Carolina

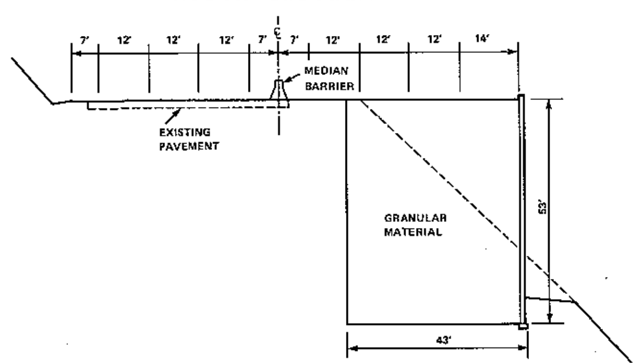

Figure 5. Typical Section - I-40 - North Carolina

New Location - As contracting agencies gain experience with Reinforced Earth, consideration of its use becomes more common in the design of highways at new locations. This type project is illustrated by the construction of a section of I-80N near Glenns Ferry, Idaho. The highway alignment traverses two areas, known as "First and Second Narrows," where the Snake River has cut a narrow passageway through the mesas that characterize the area's terrain. The Second Narrows site presented the most challenging problem from a geological standpoint. The route crosses the lower portion of an old slide area and required a design which would not impair the already marginal stability of the area. For highway alignment, the problem was to accommodate an Interstate Highway between a railroad mainline, at the edge of the Snake River, and an important irrigation canal on the steep hillside above. Retaining walls thus became a necessary feature of the roadway design.

The early stages of design in 1971 set the roadway grade based on the maximum height of retaining walls that were then being considered. The resulting sag curve was considered highly undesirable from a traffic safety standpoint. These conventional retaining structures also required cuts that were considered dangerous to the overall stability of the hillside. With Reinforced Earth walls, the Idaho Transportation Department found they could increase the maximum wall height, modify the grade to produce a safer section and most important, significantly reduce the quantity of material to be removed from the hillside. In 1972 the Reinforced Earth Company developed a design for the Second Narrows using two major retaining walls, one between the frontage road and the eastbound I-80N and one between the east and west bound I-80N lanes. Two minor walls were designed to retain a portion of the frontage road above the railroad. Two minor walls were also required between the west bound lane of I-80N and King Hill Canal. Figures 6 and 7 illustrate a plan and section view of the project respectively. The entire project involved approximately 200,000 square feet of wall with a maximum height of 45 feet. Wall construction began in the summer of 1977 and required approximately 20 weeks. The average erection rate was 10,250 square feet of wall per week. Figure 8 shows the site after construction was completed.

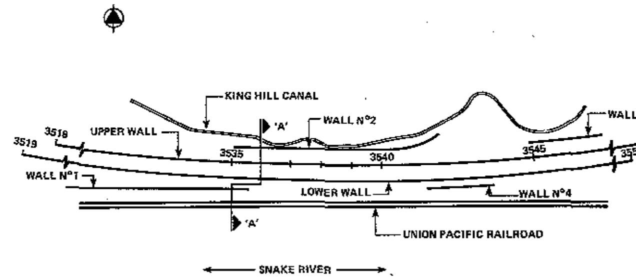

Figure 6. Plan View - Second Narrows, Idaho

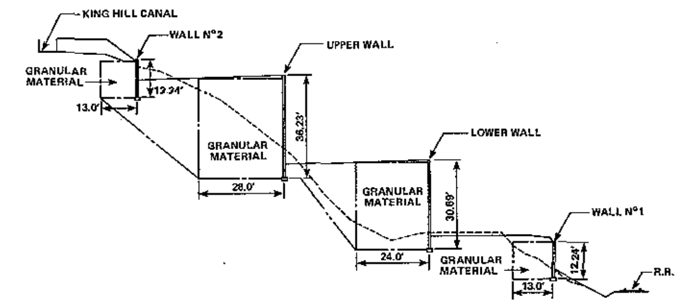

Figure 7. Section View - Second Narrows, Idaho

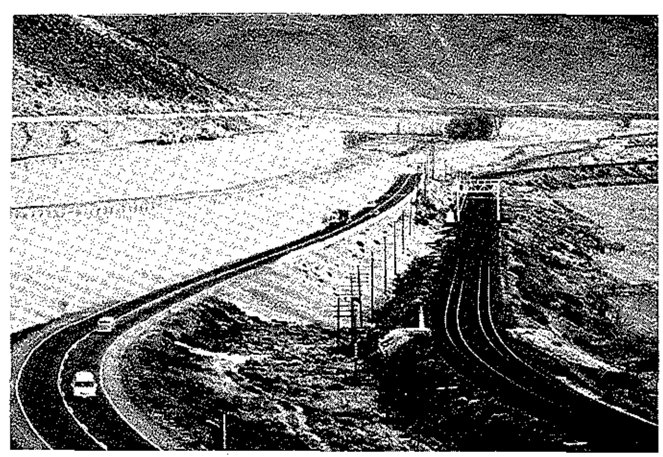

Figure 8. Completed Project - Second Narrows, Idaho

CONCLUSIONS

A change in the direction of the transportation program in the United States is evident. The 42,000 mile, 100 billion dollar Interstate System, started in 1956, is near completion. While some construction involving new location is still planned, reconstruction and upgrading of existing facilities will be of high priority for several years. On these type projects, considerations of: Construction time, economics, safety through construction zones, environment and limited right of way are all, extremely important. Since its first use in 1969, Reinforced Earth's application and role in this changing transportation system continues to expand and grow. A majority of initial Reinforced Earth projects involved correction of construction problems and were implemented in a "last resort" atmosphere. Success of these early applications resulted in the acceptance of the system as a standard design procedure for the retention of earth forces. Recent applications have been widely diversified and include: Slide corrections, bridge abutments, and Reinforced Earth slabs. In spite of this growth, a review of future transportation needs reveals that only a small portion of the potential market has been developed thus far.

REFERENCES

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