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Backfill for reinforced earth structures: south Africa experience

Le remblai dans les ouvrages en terre armée : expérience Sud-Africaine

La technique de la terre armée a trouvé des applications en Afrique du Sud dans les domaines des travaux publics, des mines et de l'industrie, et l'expérience a conduit à un travail systématique de recherche de sources convenables de matériau de remblai.

Dans les régions urbaines, on s'est surtout intéressé aux déchets miniers et industriels, dans les régions rurales, au contraire, aux sols naturels, les recherches géologiques pouvant de temps en temps faire appel à des techniques complexes telles que la cartographie des terrains par interprétation de photos aériennes.

Le coût du remblai peut parfois jouer un rôle important dans la faisabilité économique du projet, et dans chaque cas, les études correspondantes devraient être menées aussi tôt que possible.

INTRODUCTION:

The reinforced earth concept was first introduced into South Africa in 1975 and since that date about 30 projects have been brought to fruition in the fields of public works, mining and industry. In the light of the above experience this paper develops a basic approach to the problems of procurement, selection and utilization of backfill, which can on occasions play a role in the determination of the feasibility of a specific project.

The paper deals only with economic and planning aspects of the problem and does not discuss mechanical and chemical requirements which are well-known and have been laid down as a result of research and experience over the years. The search for backfill as described in the paper is based on present-day specifications but will no doubt adapt itself to changes in the specifications as and when these occur.

GENERAL APPROACH:

The approach to locating suitable backfill has been found to be governed by three basic sets of circumstances, urban, rural and mining.

In urban projects the procurement of backfill has been found to be governed, firstly, by the high price of land (even if undeveloped) and, secondly, by restrictions in regard to expropriation, town-planning and environmental pollution. The chances of using natural deposits have been found to be minimal and soil and geological studies have therefore taken second place to the search for man-made materials, usually found in the form of industrial and mining wastes.

The types of activities producing such wastes include:

i) the sand and quarry industries where the production of aggregates for building and civil engineering construction almost invariably result in the creation of stockpiles of overburden and of undersize and oversize products of crushing;

ii) steelworks where air-cooled blast-furnace slag is capable of being processed into aggregates for the construction industry;

iii) mining operations;

iv) coal-fired power stations which produce large quantities of pulverized fuel ash. This latter material has not yet been used as backfill for reinforced earth but it could provide a significant source in certain areas provided its grading meets the specification and its corrosion characteristics can be dealt

with:

v) surplus excavations usually from construction operations.

Johannesburg itself is a unique case where, over a period of about 90 years, hundreds of millions of tons of sand and slimes have been deposited in dumps in and around the city. This vast quantity of waste is not totally available for backfill nor is it in fact required. Certain of the dumps still contain residual gold and mining law forbids their being used for construction purposes, others are highly contaminated by sulphates or, in the present state of reinforced earth specifications, have unacceptable grading characteristics. The acceptable proportion of the total quantity is probably small but its volume is appreciable and probably quite adequate for short - and medium - term requirements. Throughout Johannesburg and its neighbouring towns and cities the locations, volumes, chemical and physical characteristics, and ownership of the dumps has been recorded and this information is used as a preliminary guide to the study of potential reinforced earth projects in the region.

Coastal cities in South Africa have been found to fall into a separate category from their inland counterparts because of the availability of beach sand and sometimes, as in the case of Cape Town, of dune sand. These sands usually have acceptable gradings and the overriding technical consideration is that of corrosion.

In rural areas the approach has had to be oriented to the study of local geology and soils. Mining and industrial wastes are scarce or totally absent, quarry activities are usually small-scale and their waste products expensive. In many cases backfill has been located without having to carry out intensive studies because the sources have been obvious and land values low. Problems only start to occur in regions where clay soils predominate. In these cases more sophisticated exploration procedures have been adopted and the most rapid and successful of these procedures has proved to be soil mapping aided by air-photo interpretation. This is a technique used widely in South Africa for location of materials for highway construction and the expertise is therefore readily at hand.

The economy of South Africa has been built on its mineral wealth and a large variety of mining enterprises are scattered throughout the length and breadth of the country. Reinforced earth has found useful applications in mining; and backfill has on occasions presented problems, although never of such a nature as to exclude completely the possibility of using the material. Mines are often located in remote localities where sources of natural backfill are available as in the case for ordinary rural projects.

When natural suitable material is not present waste products resulting from mining activities can often be used. Furthermore, large-scale mining development involves establishment of a local infrastructure which in turn means that crushed rock, sand, crusher wastes and crusher overburden could be available close at hand.

SOME ILLUSTRATIVE PROJECTS:

The following list of projects give an indication of the experience on which the above general principles have been based:

Project, Location & Nature of Service		*Backfill Problems*
George's Valley N. Transvaal - Mountain Road	:	High rainfall area - clay soils - original plan to use crusher waste as backfill material - high cost due to purchase price and long haul - alternative source found by air-photo geological interpretation - subsequent further alternative located by contractor.
Alberton, near Johannesburg - Bridge Abutment	:	Reinforced earth design prepared as an alternative - source of backfill about 25Km. from site - cost saving minimal - subsequent to tender a closer source of backfill was located but too late to secure project.
Consolidated Diamond Mines, Namibia (CDM) - tip wall for ore processing	:	Mine situated on Atlantic Coast - highly corrosive local sands used as backfill - despite cost of cathodic protection the readily available backfill rendered the structure cheaper than reinforced concrete alternative.
Koingnaas Diamond Mine, Cape - terracing for a gravity-feed process	:	Same region and type of backfill as CDM above - as an alternative to cathodic protection galvanized steel with sacrificial thickness was used in the corrosive backfill - reinforced earth alternative again less expensive than other forms of construction.

ISCOR Steel Works Pretoria - Railway embankment	:	Crushed aircooled slag used as backfill – 37mm crusher-run produced on the property and search for natural materials obviated.
Rietspruit Railway - Eastern Transvaal - bridge abutments.	:	Geological investigations failed to find a source of natural backfill - crusher waste from adjacent mining development was eventually chosen as backfill.

COST CONSIDERATIONS:

In studying the feasibility of using reinforced earth on specific projects it has usually been necessary to compare their estimated total cost with that of the more conventional forms of construction, the principal alternatives in South Africa being reinforced concrete or gabions. Cost has not been the only deciding factor but its influence has more often than not been overriding.

The cost of panels and reinforcing strips can be determined reasonably accurately as can the cost of material for reinforced concrete or gabion alternatives. The unknown factor often proves to be the cost of reinforced earth backfill which unlike that for backfill against a reinforced concrete wall has to conform to standards of grading and chemical content. As a guide to cost comparisons the total quantity of backfill in a reinforced earth structure is about 4 - 6 times the quantity of aggregates (sand and stone) required in the reinforced concrete alternative.

Backfill is not always a problem. In several instances as has been pointed out, backfill has been readily available and the only extra cost to be charged to reinforced earth has been for the additional effort required for spreading and compaction. In South Africa contractors usually quote an extra-over to their basic earthworks price of between 30 and 60 US cents per cubic metre.

Availability of good backfill can also represent a distinct cost saving. This occurs in remote areas where the costs of concrete aggregates are excessive, and is of particular significance in the early stages of a mining development i.e. before the main infrastructure has had the time to be established.

CONCLUSIONS AND RECOMMENDATIONS:

i) In studying the feasibility of reinforced earth projects it is seen that certain of them are sensitive to the cost and availability of backfill. It is therefore important to look into the backfill problems of each and every project and at an early a stage as possible. This precaution will obviate wasted effort on the design of the structure itself in the event of backfill proving to be too costly. Conversely, if an economical source of backfill is established at an early stage designers will tend to follow the project with greater enthusiasm and purpose.

ii) Detailed and costly exploration surveys are often justified in that sources of backfill are discovered which make the project more attractive from the viewpoints of cost and speed of construction. The cost of the survey becomes insignificant in relation to the size of the total project.

iii) In urban areas it is essential to investigate the cost, availability and quality of waste materials. In addition to savings in cost, the use of waste materials helps, if only in a limited way, to alleviate environmental and pollution problems.

iv) The South African experience, although until now rather heavily reliant on mining operations, could probably prove of assistance to the reinforced earth movement in other countries; more especially to those with a developed or developing mining industry.