Use of Excavated Excess Soils in Earth Works

Akiomi Shimazu

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. Treatment of such excess soils have become pressed problems to solve. Systematic research has been performed for several years in governmental bases over development of utilization technique including soil classification system and some other factors. This paper firstly describes soil classification in normal practice in road earth works and then introduces the methods of utilization of excavated excess soil to earth works along with the manual of excess soil utilization which has been published in 1997 by Public Works Research Center under collaboration of Public Works Research Institute and private companies.

Dear Mr. J. Davaasuren,

I am now sending abstract of my proposed paper titled as "Use of excavated excess soils in earth works". I shoud apologize delay of submission of my paper, however, I am still in processing the complete one. I will bring full paper with me in Ulaanbaatar. At the presentation I would like to use OHP.

Sincerely Yours,

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USE OF EXCAVATED EXCESS SOILS IN EARTH WORKS

Abstract

Recent urban development has brought large outcome of excavated excess soils those which are not adequate materials for direct use to construction with properties of fine grain particles and high water contents originated from alluvial land.

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1. Introduction

Balancing volume of cut and fill is normal practice in earth works planning. In this process when soils not adequate for fill are encountered, those soils are abandoned nearby or transported to land reclamation sites. However, such treatments have not welcome due to recent shortage of such sites and arising socio-environmental demand. And more over recent urban construction with underground facilities such as buildings, subways has brought large outcome of excavated excess soils which are not adequate materials for direct use to construction with properties of fine grain particles and high water contents originated from alluvial land.

Above mentioned treatment of excess fine grain soils have become pressed problems to solve. Systematic research has been performed for several years in governmental bases over development of utilization technique including soil classification criteria, circulation system of carry-out and acceptance information, feasibility of soil improvement plant and stock yard net work, studies on creation of soil mass oriented constructions such as in-land reclamation in low areas.

Among the researches this paper introduces the methods of utilization of excavated excess soil to earth works along with the manual of excess soil utilization which has been published in 1997 by Public Works Research Center under collaboration of Public Works Research Institute and private companies.

2. Japanese Classification System of Soil used for Earth Works of Roads

For judge engineering properties of soil, i.e., evaluation of soil tests etc., the international unified classification system which is based on sieve passing analysis and Atterberg limits has been used in principle (slightly modified for Japanese local soil of volcanic ash clay or alluvial clay). However, in-situ soils are usually treated in more wide ranged classification by working bases or by local soil property bases. Also later mentioning excavated excess soils are classified by another concept mainly by easiness of treatment in transportation and compaction works.

The earth works design of ordinary national roads and main local roads are based on "earth works manual" (Japan road association). The earth works manual consists of 8 separate volumes; i.e. soil survey, earth works planning, drainage planning, slope protections, soft ground measures, retaining walls, culverts, temporary supports. Those have been revised every 10 to 15 years. The following classification system are introduced by this manual(earth works planning). For the express highways there are another standards based on more strict performance demand.

(1) Evaluation standard of materials for road earth works

Table-1 Evaluation standard of materials for road earth works

classification		Embankment	Sub-grade*	Natural Ground	Remarks
Rocks, Boulders		△	X	○	Depends on size of fraction
gravels	G	○	○	○	
Gravels mixed with sands and fine materials	GF	○	△	○	If mixed with organic or volcanic fines, grade will be lowered
sands	S	○	○	○	Loose sands are not adequate for ground
Sands mixed with fine materials	SF	○	△	○	If mixed with organic or volcanic fines, grade will be lowered
Silt	M	△	△	△	
Clayey Soil	C	△	△	△	
Volcanic ash clays	V	△	△	△	
Organic Soils	A	△	X	△	
Highly organic soils	P_t	X	X	△	

○ : suitable △ : used with some treatment X : not compliant

* : subgrade is defined as the top 1 meter layer of embankment

For fill materials it will be ideal to satisfy the condition of easy spreading and compaction treatment, large strength, very small compression or depression, toughness against erosion and no expansion by heavy rain, etc. Table-1 shows evaluation standard of soil materials for road earth works.

(2) Standard gradient for embankment

Table-2 shows standard gradient for embankment by soil class.

Table-2 Standard gradient for embankment

Fill materials (unified classification)		Height of embankment	Gradient (vertical : horizontal)
Well graded sand Gravel Gravel mixed with fine materials	SW GM,GC GW,GP	5 m below	1:1.5 – 1:1.8
		5 – 15 m	1:1.8 – 1: 2.0
Poorly graded sand	SP	10 m below	1:1.8 – 1:2.0
Rock fraction (includes Debris of tunnel works)		10 m below	1:1.5 – 1:1.8
		10 – 20 m	1:1.8 – 1:2.0
Sandy soil Stiff clayey soil Stiff clay(diluvial layer)	SM,SC	5 m below	1:1.5 – 1:1.8
		5 – 10 m	1:1.8 – 1:2.0
Volcanic ash clay	VH_2	5 m below	1:1.8 – 1:2.0

Note : values applicable for embankments on stiff ground and of no submergence

(3) Standard gradient for cut slopes

Cut slope materials are of in-situ condition and not like those of embankment in selective basis. As a reference table-3 shows standard gradient for cut slopes

Table-3 Standard gradient for cut slopes

Slope materials in-situ		Height of cut	Gradient (vertical : horizontal)
Hard rocks			1:0.3 – 1:0.8
Soft rocks			1:0.5 – 1:1.2
sands	Not dense and poorly graded		1:1.5 -
Sandy soils	dense	5 m below	1:0.8 – 1:1.0
		5 – 10 m	1:1.0 – 1:1.2
	Not dense	5 m below	1:1.0 – 1:1.2
		5 – 10 m	1:1.2 – 1:1.5
Gravels Sandy soils mixed with rock fraction	Dense and well graded	10 m below	1:0.8 – 1:1.0
		10 – 15 m	1:1.0 – 1:1.2
	Not dense or Poorly graded	10 m below	1:1.0 – 1:1.2
		10 – 15 m	1:1.2 – 1:1.5
Clayey soils (includes silt)		10 m below	1:0.8 – 1:1.2
		5 m below	1:1.0 – 1:1.2

Clayey soils mixed with rock fraction or boulders		5 m below	1:1.0 – 1:1.2
		5 – 10 m	1:1.2 – 1:1.5

Note : berms are not included in gradient

(4) Backfill materials for structures in approach embankment

Materials placed in the backfill of structures(bride abutments etc.) are carefully selected so as not to cause faulting settlement over road surface. Table-4 shows requirement for such backfill materials to keep low compression and good drainage performance.

Table-4 Requirement for backfill material in approach embankment

items	requirement
Maximum grain size	100 mm below
4760 μ (no.4)sieve passing	25 – 100 %
74 μ (no.200)sieve passing	0 – 25 %
Plasticity index(for 420 μ passing)	10 below

(5) Requirement in compaction control

For embankment portion soils are placed and sprayed within 30 cm thickness and compaction requirement is as follows:

(a) Proctor's compaction requirement

In general for soils not in high water content

Degree of compaction : 90% or more (for maximum dry density by 2.5Kg rammer – 30cm height)

Site water content : range between optimum water content and water content corresponding to 90% compaction (wet side)

(b) Air void or degree of saturation requirement

For soil not along Procter's curve (high water content in natural condition - cohesive soil)

Air void : 10% or less

Degree of saturation : 85% or more

(c) Control of coverages by compaction machines

For embankment of large earth works volume or soils need special care.

In principle this methods need site compaction tests prior to fix compaction machinery and numbers of coverages.

For subgrade(defined as top 1 meter layer of embankment) selected soils in-situ are placed and sprayed within 20 cm thickness and compaction requirement is as follows:

(d) Proctor's compaction requirement

Degree of compaction : 95% or more (for maximum dry density by 2.5Kg rammer – 30cm height)

Site water content : range between optimum water content and
water content corresponding to 95% compaction
(wet side)

3. Soils need careful treatments

(1) Soils not to be used for road embankment

Together with the highly organic soils marked as "X" in table-1, the following soils are not to be used for road embankment:

- bentonite, acid white clay, soils of highly humus content, iced soil or soils of ice and snow mixed.

(2) Excavated fine grain soils with high water content

Fine grain soils with high water content are not suitable for road earth works for their poor engineering properties and those soils need careful treatment of improvement such as decreasing water content or chemical stabilization. And those soils are not clearly classified or evaluated in table-1. However, the outcome increase of such soils and necessity of recycling have brought the development of utilization methods and composing manual how to classify such soils and where to apply. The treatment of those soils will be described in the chapter 4.

(3) Soils need special care for embankments

Following soils are to be carefully treated in design, construction and maintenance stages.

(a) volcanic ash clay

characteristics : soils of liquidity index((Wn-PL)/(LL-PL)) less than 0.8 will be difficult in construction(trafficability). Subject to excess pore water when layered in quick speed

measures : dry in spread layer, layered in slow speed, place berms or horizontal drainage layers, avoid repeated compactions

(b) erosive sandy soil

characteristics : easy surface erosion and wash away of soil particle when very low cohesion, especially the case of low light weight particles.

measures : place covering top layer, place horizontal drainage layers, avoid water spilled over the sloping surface in construction (place shoulder drainage or central drainage in compaction layer to let water drained to another part such as sedimentation pond)

(c) slaking prone rock materials

characteristics : Rocks such as mud stone, shale or tuff are suspicious of crushed in fine particles due to repetition of wet and dry weathers(slaking), apt to be cause of large settlement of embankment after completion measures : avoid to use in embankments of large traffic volume, high embankments , backfill portion and water submerged portion. Drain underground water

Crushed compaction by heavy or vibration roller in thin layers aiming at low air void less than 15%

(d) large rock fraction

characteristics : large shearing resistance, good drainage, good performance without slope protection

large particle size resulting thick layer spreading and bringing difficulty of compaction control, apt to cause material separations

measures : keep spreading thickness within 1 to 1.5 times of maximum particle size and use heavy compaction machine.

Place larger fractions to lower part of embankment or sloping part.

Place middle sized zones when ordinary sized subgrade is placed on the rock embankment.

(4) Embankments need special care

Embankment of following condition are needed special care and are designed basing on the earth manual.

(a) embankment placed on inclined foundation ground

Treatments of water flow are important avoiding water inflow to embankment portion, drainage of inside water from the embankment, and lowering underground water table if any.

(b) boundary zone between fill and cut

Place transition zone to avid discontinuity of bearing strength.

(c) embankment on soft foundation ground

Set free board on height as well as slope gradient considering settlement of foundation ground during and after completion. Also same is for drainage facilities

(d) compressive settlement of fill materials

For slaking prone materials from cut works or tunnel excavation, already mentioned method in (3-c) will be used.

For cohesive soils with high water content, drainage layers are installed to decrease water content inside the embankment.

(e) embankment of erosive sandy soil

Already mentioned methods in (3-b) will be used.

(f) faulting between structures and fill of approach embankment

Use selected materials shown in table-4 to decrease faulting settlement. Or adopt pre-loading fill on the portion. Approach cushion slab is also available.

(g) embankment in cold weather area of snow and ice

Fine grain soils(ML,MH,OL,OH,CL,CH and volcanic ash clay) and presence of under ground water cause frost heave or freeze-thaw causing slope failures. Measures are replacement by selected materials and install drainages, increase weight of crib member of slope protection etc.

(h) earthquake resistant design of embankment

Most important measure is strengthening of foundation ground if composed of liquefaction prone layer. Approaching part to bridge abutment is required careful treatment for faulting by use of selected materials

4. Manual for Excavated Excess Soils to Earth Works

As described in 3(2), the manual for excavated excess soils has published in 1997 and treatments of such soils have been performed basing on this manual in governmental organizations.

Classification standard for excavated excess soils are shown in table-5 and the fields of application are recommended in table-6 with recommended improvement methods newly developed by collaboration of Public Works Research Institute and private companies.

As for improvement methods, the expected functions, applicable field conditions and soils to be applicable are shown in table-7, table-8 and table-9 respectively.

Table-5 Japanese classification standard for excavated excess soils

Class of Excess soil	Sub-division	Cone Index qc	Unified soil classification		Water content (natural gr.)
				Soil equiv.	
1st excess soil (sand, gravel & so)	1st		{G}	Gravel	—
			{S}	Sand	—
	1st improved			(improved soil)	—
2nd excess soil (sandy soil, gravelly soil & so)	2a	800KN /m2 or more	{GF}	Gravelly soil	—
	2b		{SF}	Sandy soil (Fc : 15-25%)	—
	2c			Sandy soil (Fc : 25-50%)	30% less
	2nd improved			(improved soil)	—
3rd excess soil (clayey soil & so applicable to normal works)	3a	400KN /m2 or more	{SF}	Sandy soil (Fc : 25-50%)	30-50%
	3b		{M},{C}	Silt, Clayey soil	40% less
			{V}	Volcanic clayey	—
	3rd improved			(improved soil)	—
4th excess soil (clayey soil & so except 3rd one above)	4a	200KN /m2 or more	{SF}	Sandy soil (Fc : 25-50%)	—
	4b		{M},{C}	Silt, Clayey soil	40-80%
			{V}	Volcanic clayey	—
			{O}	Organic soil	40-80%
	4th improved			(improved soil)	—

Muddy soil (dredged soil of qc less than 200KN/m2)	Muddy a	200kN /m2 less	{SF}	Sandy soil (Fc：25-50%)	—
	Muddy b		{M},{C}	Silt, Clayey soil	80% less
			{V}	Volcanic clayey	—
			{O}	Organic soil	80% less
	Muddy c		{Pt}	Highly Organic	—

qc： cone penetration resistance(3.24cm2 & 30° cone) on compacted sample in the compaction mold(ϕ 100mm, 127mm height, in 3 layers, 25 blows on each layer of 30cm falling height of 25N rammer)

Fc：fine grain content less than 74 μ

Table-6 Field of application of excess soils (for roads)

Class of Excess soils		Backfill to Narrow space		subgrade		Backfill to structures		embankment	
			methods		methods		methods		methods
1st	1	◎	Used as it is	◎	Used as it is	◎	Used as it is	◎	Used as it is
	1 im	◎	Used as it is	◎	Used as it is	◎	Used as it is	◎	Used as it is
2nd	2a	◎	Used as it is	◎	Used as it is	◎	Used as it is	◎	Used as it is
	2b	◎	Used as it is	◎	Used as it is	◎	Used as it is	◎	Used as it is
	2c	○	Sand mix Stablized liquefied	◎	Used as it is	◎	Used as it is	◎	Used as it is
	2 im	◎	Used as it is	◎	Used as it is	◎	Used as it is	◎	Used as it is
3rd	3a	○	Sand mix Sq water Stabilized Liquefied	○	Sq water Stabilized Fiber Reinforced	○	Sq water Stabilized	◎	Used as it is
	3b	△	Stabilized Liquefied	○	Stabilized Fiber Reinforced	○	Stabilized Sandwich Reinforced	◎	Used as it is
	3 im	△	Used as it is	○	Fiber Reinforced	○	Sandwich	◎	Used as it is
4th	4a	△	Liquefied Stabilized	△	Stabilized Fiber Reinforced	○	Sq water Stabilized Liquefied Air-foam Beads	○	Sq water Stabilized Sandwich Liquefied Air-foam Beads Fiber Reinforce

	4b	△	Liquefied Stabilized	△	Stabilized Fiber Reinforced	○	Stabilized Sandwich Liquefied Air-foam Beads	○	Stabilized Sandwich Liquefied Air-foam Beads Fiber Reinforced
	4 im	△	Stabilized	△	Stabilized Fiber Reinforced	○	Sandwich	○	Sandwich Reinforced

Table-6 (continued)

Class of Excess soils		Backfill to Narrow space		subgrade		Backfill to structures		embankment	
			methods		methods		methods		methods
Muddy soil	Ma	△	Liquefied Stabilized	△	Stabilized Fiber Reinforced	△	Stabilized Liquefied Air-foam Beads	○	Sq Water Stabilized Sandwich Liquefied Air-foam Beads Fiber
	Mb	△	Liquefied Stabilized	△	Stabilized Fiber Reinforced	△	Stabilized Tube Liquefied Air-foam Beads	○	Sq water Stabilized Sandwich Liquefied Air-foam Beads Fiber Reinforced
	Mc	X	Not applicable	X	Not applicable	X	Not applicable	X	Not applicable

◎：used as it is、○：used with small improvement or treatment、

△：used with improvement or some special treatment、X：not applicable。

Sand mix : mixing with coarse grain materials to improve grading
Sq water : decreasing water content by dry, dehydration, or squeezing
Stabilized : mixing with cement or lime to stabilize soil (In-situ mixing method or Central plant mixing method)
Liquefied : liquefied stabilized soil method. Soils mixed with water and cement. Poured in place and no need of compaction work.
Air-foam : Air-foam mixed stabilized soil method. Liquefied soil mixed with air-foam to get controlled light weight property
Beads : Expanded-beads mixed light-weight soil method. Soils in-situ mixed with light weight beads(from expanded polystyrene etc.) and by case cement added. Soil-like deformability with controlled weight
Fiber : Fiber-reinforced soil method. Soils or stabilized soil mixed with short Polystyrene fiber. Anti-erosive property with good plantation base
Reinforced : reinforced earth method with geo-grid. Vertical or steep slope fill.
Sandwich : permeable geotextile layered in embankment to accelerate dehydration and consolidation
Tube : Geotextile tube dehydration method. Muddy soil pressed and dehydrated in permeable tube or sack. Composite structure of tube and soil increases strength during pile up to form fill. Plantation.

Table-7 Function obtained by improvement methods

function / methods	Expected function							
	strength	ductility	liquefy	light weigh	no compact	consolidation	plantation	other factors
In-situ stabilization	○							trafficability
Central plant stabilization	○							trafficability
Expanded beads mixed	○		○	○	○		○	deformability
Air-foam mixed stabilized soil	○		○	○	○			
Liquefied stabilized soil	○		○		○			
Geotextile tube dehydration	○	○			○	○	○	rapid decrese of volume
Fiber-reinforced soil	○	○					○	Anti-erosion
Geotextile reinforced soil	○	○				○	○	All-over stability
Sandwich dehydration	○					○	○	

○ : applicable

Table-8 Selection table for each improvement methods

condition \ methods		in-situ	cent plat	beads	air-foam	liquefy	tube	fiber	rein force	sand wich
Require soil strengthened	Cement added	○	○	○	○	○		○		
	Drain or reinforced						○		○	○
Backfill into narrow space				○	○	○				
Anti-erosion of slope		○	○					○	○	
Light weight fill on soft ground				○	○					
Compatible to Deformation of ground				○			○	○	○	○
Embankment widening In mountainous site				○	○					
Submerged embankment			○	○	○	○	○		○	○
General backfill works		○	○	○	○	○				
Steep sloping embankment				○	○			○	○	
Direct use without improvement							○	○	○	○
Strengthen of soils in Excavation & dredging		○								
Decrease of soil volume of high water content							○			○
Possible plantation after construction				○			○	○	○	○
Supply suitable ground For plantation								○		

○ : applicable

Table-9 Applicable soil class for each improvement methods

methods \ Soil class	1st	2nd			3rd		4th		Muddy soil		
		2a	2b	2c	3a	3b	4a	4b	Ma	Mb	Mc
In-situ stabilization	—	—	—	△	△	△	○	○	◎	◎	○
Central plant stabilization	—	—	—	△	△	△	◎	◎	◎	◎	○
Expanded-beads mixed light weight		○	◎	◎	◎	○	○	○	○	○	—
Air-foam mixed stabilized soil		○	○	○	○	◎	◎	◎	◎	◎	—
Liquefied stabilized soil		△	△	△	○	◎	◎	◎	◎	◎	—
Geotextile tube dehydration	—	—	—	—	○	○	◎	◎	◎	◎	◎
Fiber-reinforced soil		◎	◎	◎	◎	○	◎	○	△	△	—

Geotextile reinforced soil		○	◎	◎	◎	◎	○	○	△	△	—
Sandwich dehydration	—	—	—	—	○	○	◎	◎	○	○	—

◎ : suitable to apply、 ○ : applicable、 △ : applicable, need to consider local condition、
— : not applicable、 blank : not for adoption for soil of 1st class

5. Next Steps

The manual has been distributed to promote recycling of excavated excess soils. Continuing revision will be necessary basing on the pile up of field experiences.
Reducing costs are also big items to improve. Improvement of the method and careful watching for environmental problems of soil chemical influences are also continued.

References :

(1) "Manual for soil improvement methods for excess soil utilization promotion (in Japanese)", 1997, Public Works Research Center, Japan
(2) "Earth works manual (in Japanese)", 1990, Japan Road Association
(3) "Earth works volume, Design manual (in Japanese)", 1998, Japan Highway Public corporation