Lecture 19

NPTEL Course

GROUND IMPROVEMENT

GROUND TREATMENT WITH CEMENT

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Stabilization using cement and cementitious materials

Stabilization using cement and other admixtures such as fly ash, blast furnace slag has been adopted in many geotechnical and highway engineering projects. These applications include

a)Shallow depth applications in the case of improvement of subgrade, sub-base and base course of highways and embankment material

b) Stabilization of deep soil deposits such as soft soils and peaty soils.

❖Addition of small quantities of cement proved to be beneficial and the degree of strength/ stiffness required is the basis for design and has been used in the stabilization of highways and embankments.

❖In large scale applications, depending on the strength and stiffness required based on the type of soil, the quantities required are huge and need large scale machinery and special procedures are required in stabilization of deep soils which are weak (Eg: peaty soils).

Benefits:

- ❑ Increased strength and stiffness
- ❑Better volume stability
- ❑Increased durability

Factors influencing the strength and stiffness improvement

- Cement content, water content combined into water/cement(w/c) ratio.
- Method of compaction.
- Time elapsed between mixing and compaction.
- Length of curing.
- Temperature and humidity.
- Specimen size and boundary effects.

Strength gain is given by:

$$q_u(t) = q_u(t_0) + k \log \frac{t}{t_o}$$

$q_u(t)$ = the UCC (unconfined compression) strength at t days

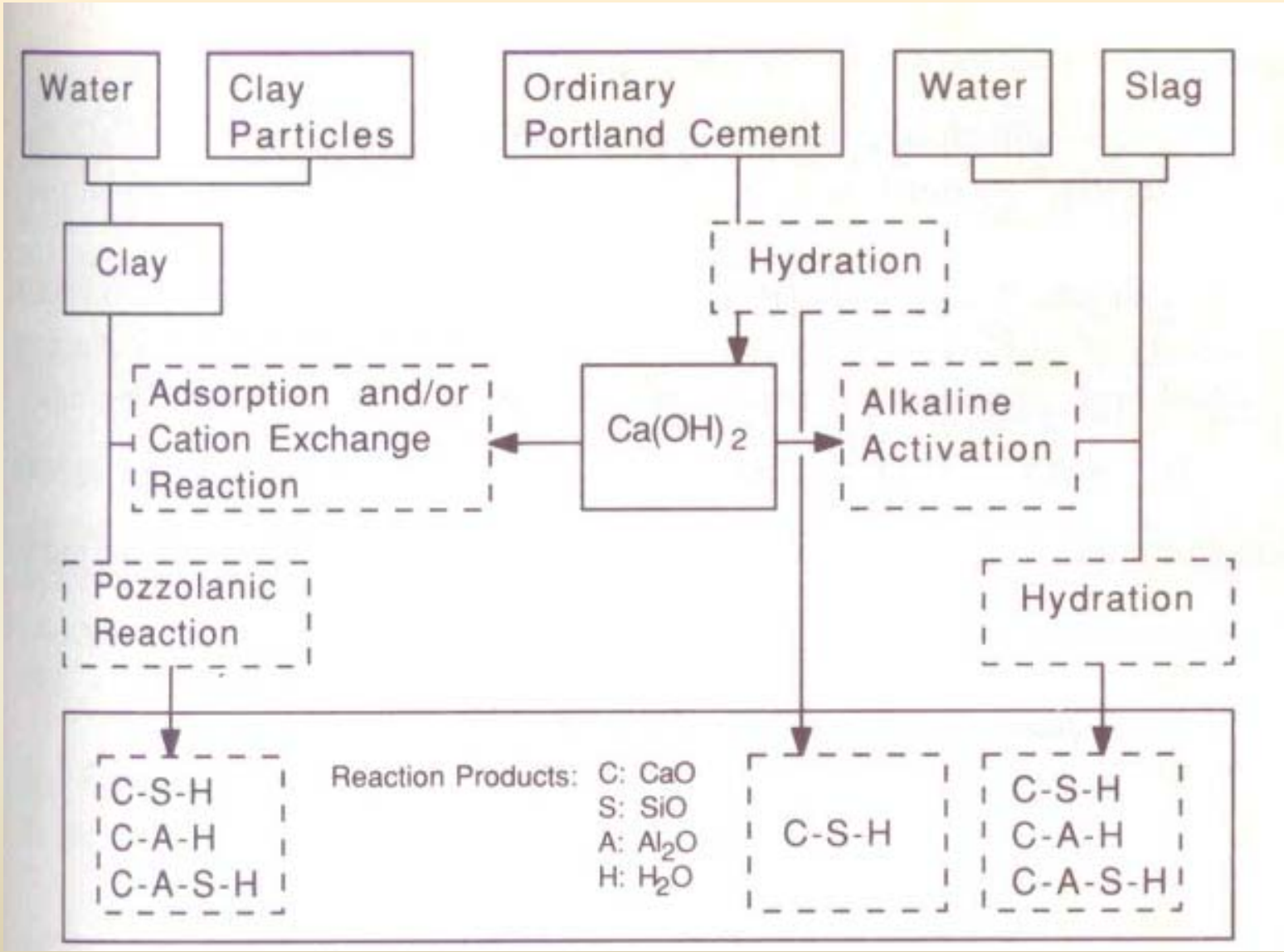
$q_u(t_0)$ = the UCC strength at t_0 days

k = 480C for granular soils; 70C for fine grained soils

C = Cement content by weight

Effect of adding cement and blast furnace slag leads to the following chemical reactions:

- Hydration of cement produces $Ca(OH)_2$. The calcium hydroxide generated is upto 25% of the weight of cement.
- Adsorption of $Ca(OH)_2$ by the clay, cation exchange reaction
- If the clay is saturated with $Ca(OH)_2$, a pozzolonic reaction between the components occurs.



Chemical reaction between soil and hardening agents.

The design and construction of a soil treatment project is generally as follows:

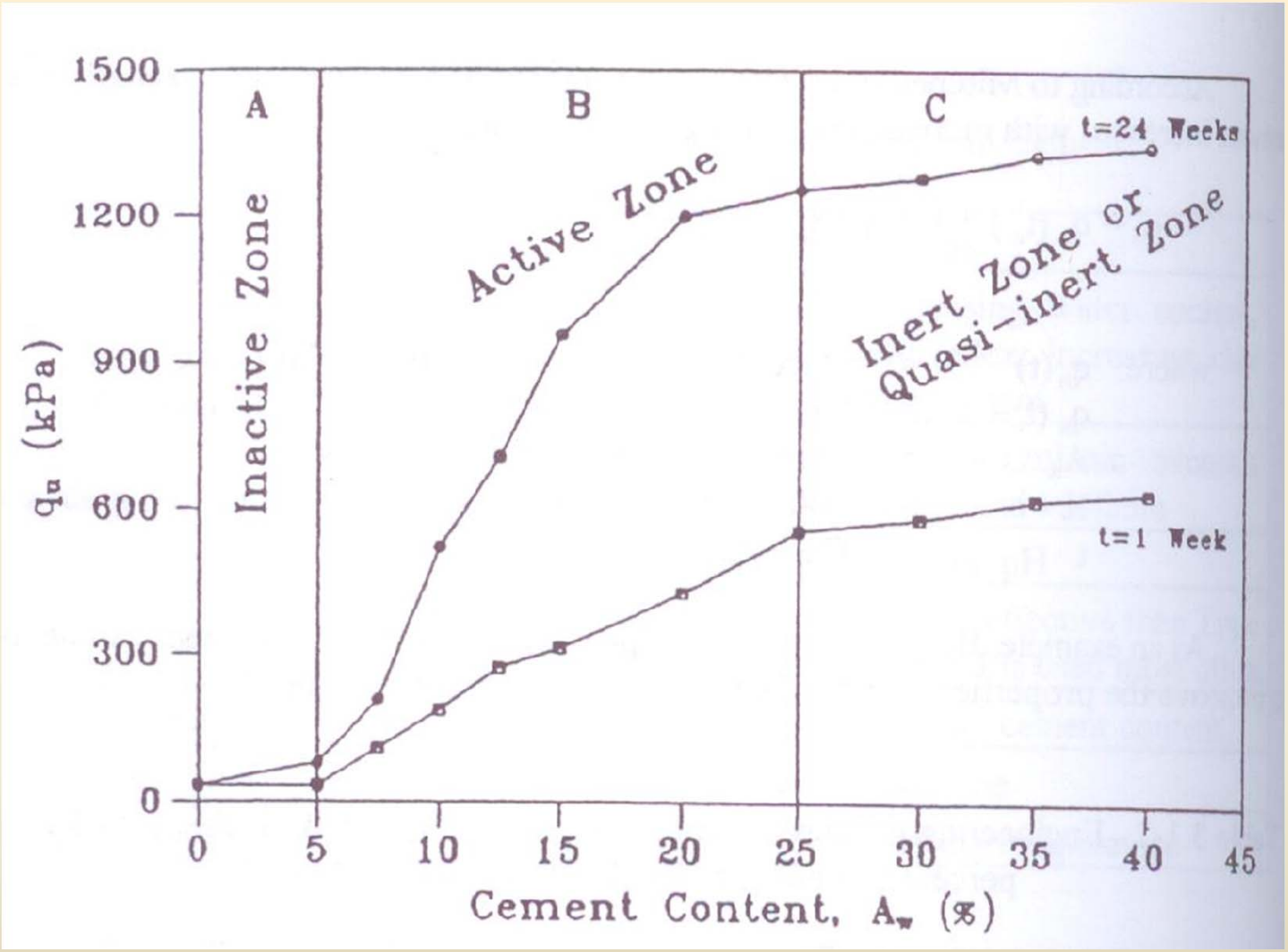
- ❖Site exploration discloses geotechnical conditions that don’t meet design criteria such as density, consistency, strength, or permeability.
- ❖Alternative treatment methods are evaluated.
- ❖Specialty contractors are selected.
- ❖Laboratory mix testing is conducted to provide guideline on in situ soil characteristics, tolerable admixture properties, and optimum mix designs
- ❖Owner approves contractor’s equipment, methods, and mix design.
- ❖Soil at site is treated with close supervision, sampling, and testing in the field to make sure that project requirements are met.

Results of Bergado et al (1996)

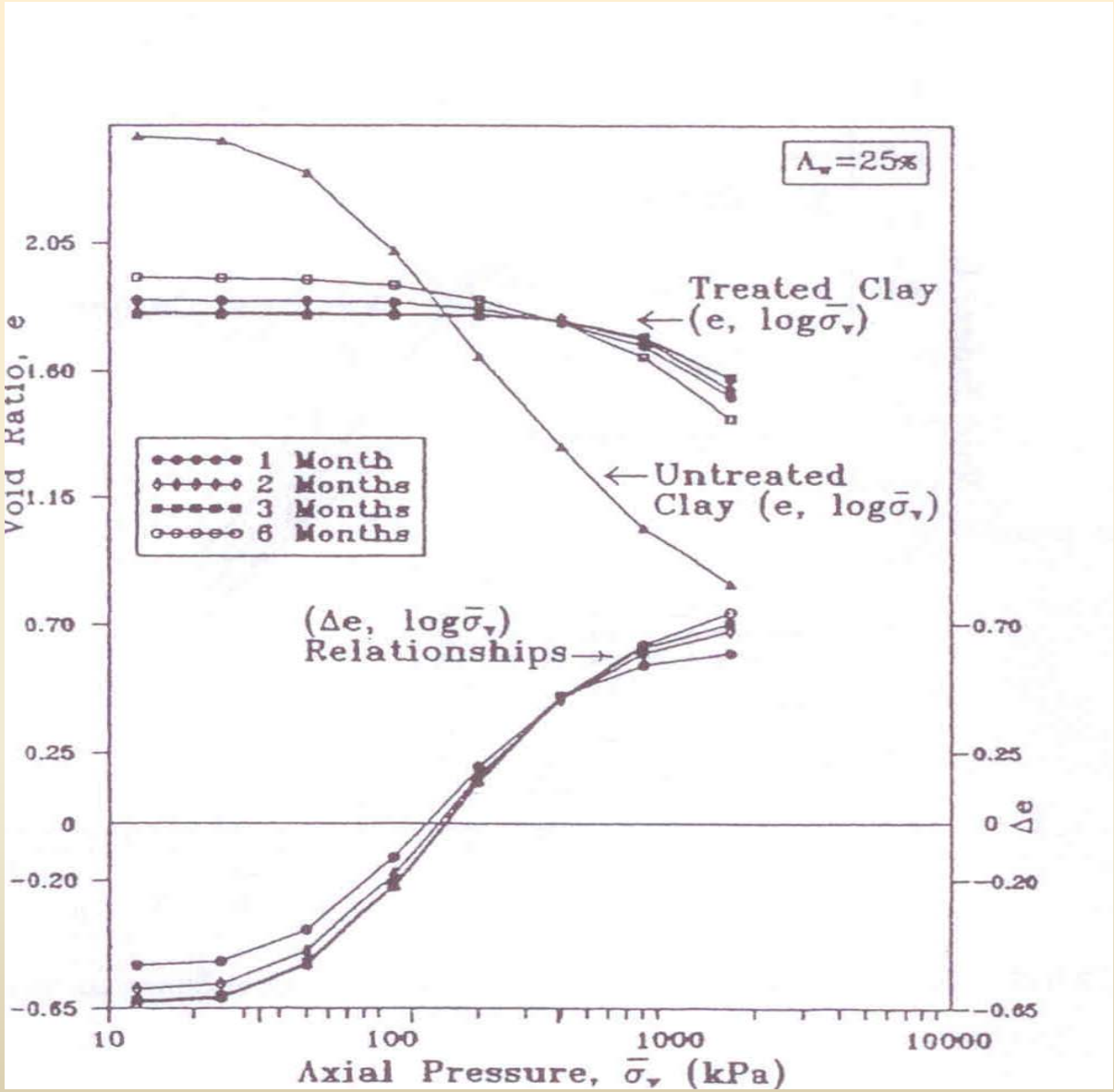
Results showed that mixing of 10% cement for the soft soil of Bangkok indicated that the UC strength and the pre-consolidation pressure are improved by ten to twenty times and two to four times respectively.

The coefficient of consolidation improved by 10 to 40 times.

Hence they considered about 10 to15 % of cement content as optimum content.



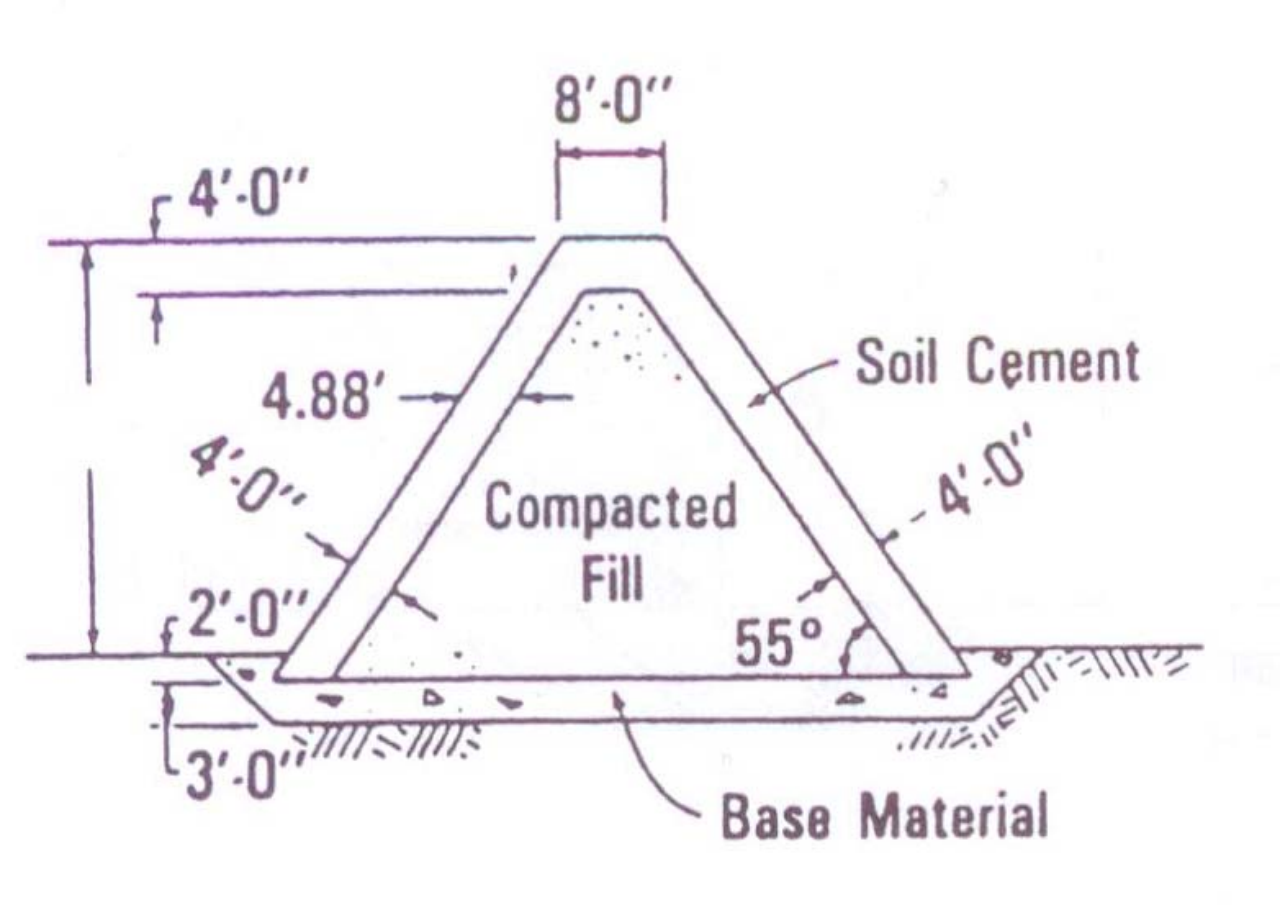
Influence of cement content on unconfined compression strength Bergado et al (1996)



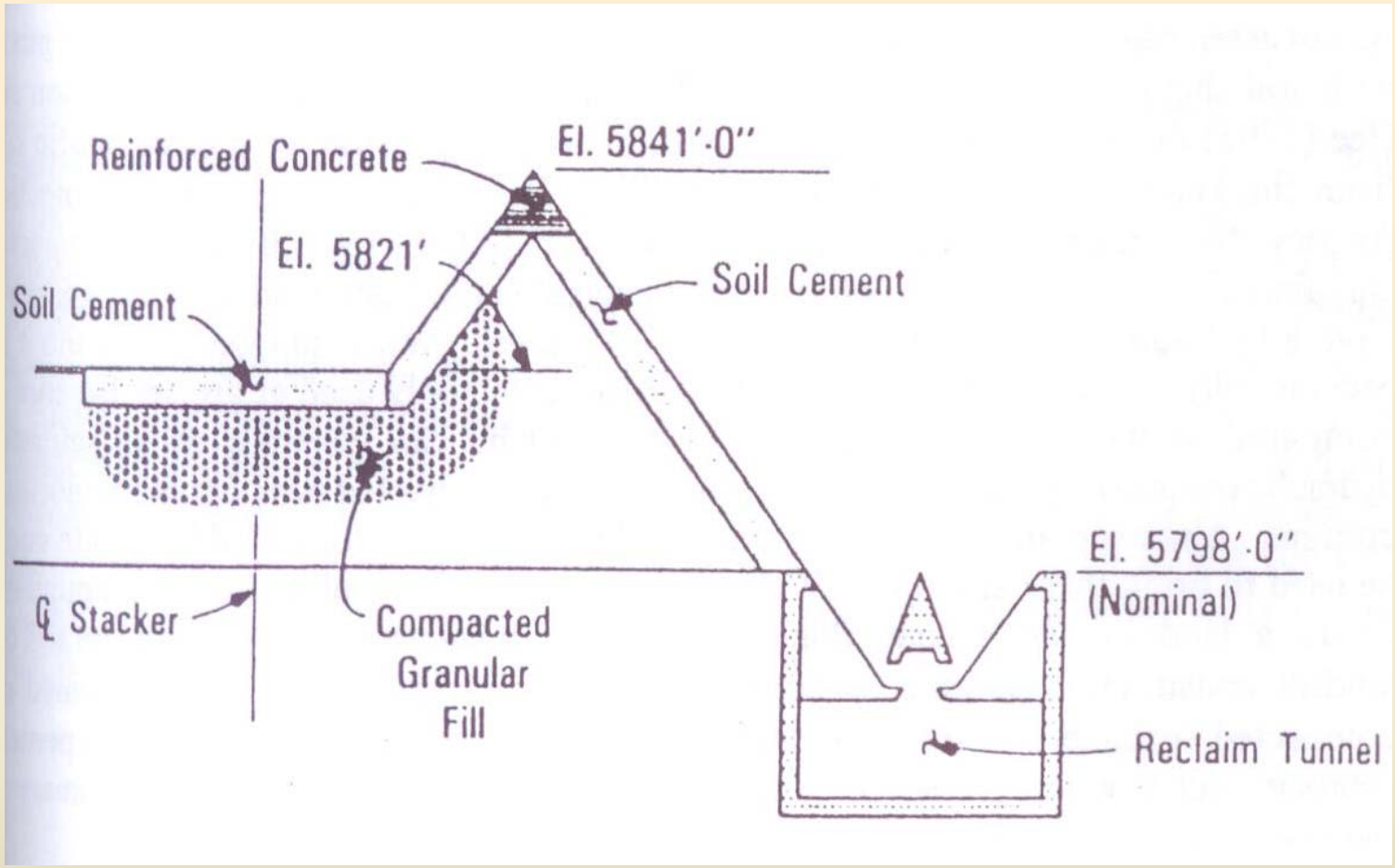
Void ratio vs. vertical pressure

Van Riessen and Hansen (1989) showed that soil cement is an excellent combination and used for retaining berms for coal piles which performed well over 25 years. The soil cement was mixed in a pug-mill and placed using a modified asphalt paver.

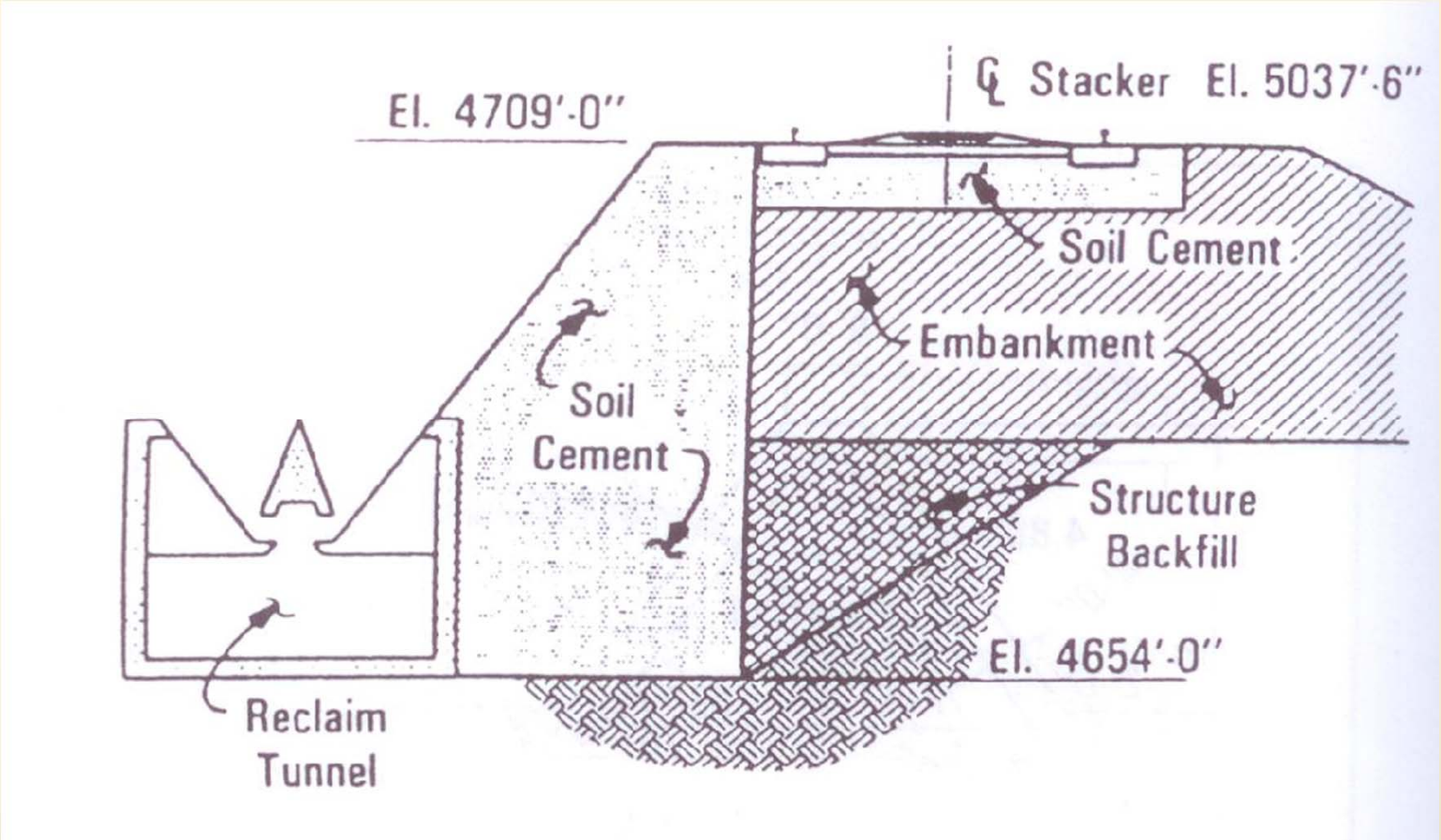
AASHTO Soil	Cement Content (Percent)	Cohesion (kPa)	Slope Angle (Degree)
A-2-4	0-8.0	138-690	29-49
A-1-b	0-5.0	69-655	38-55
A-4	0-9.5	5-125	37-45



Typical section of soil cement coal-retaining berm



Typical berm section

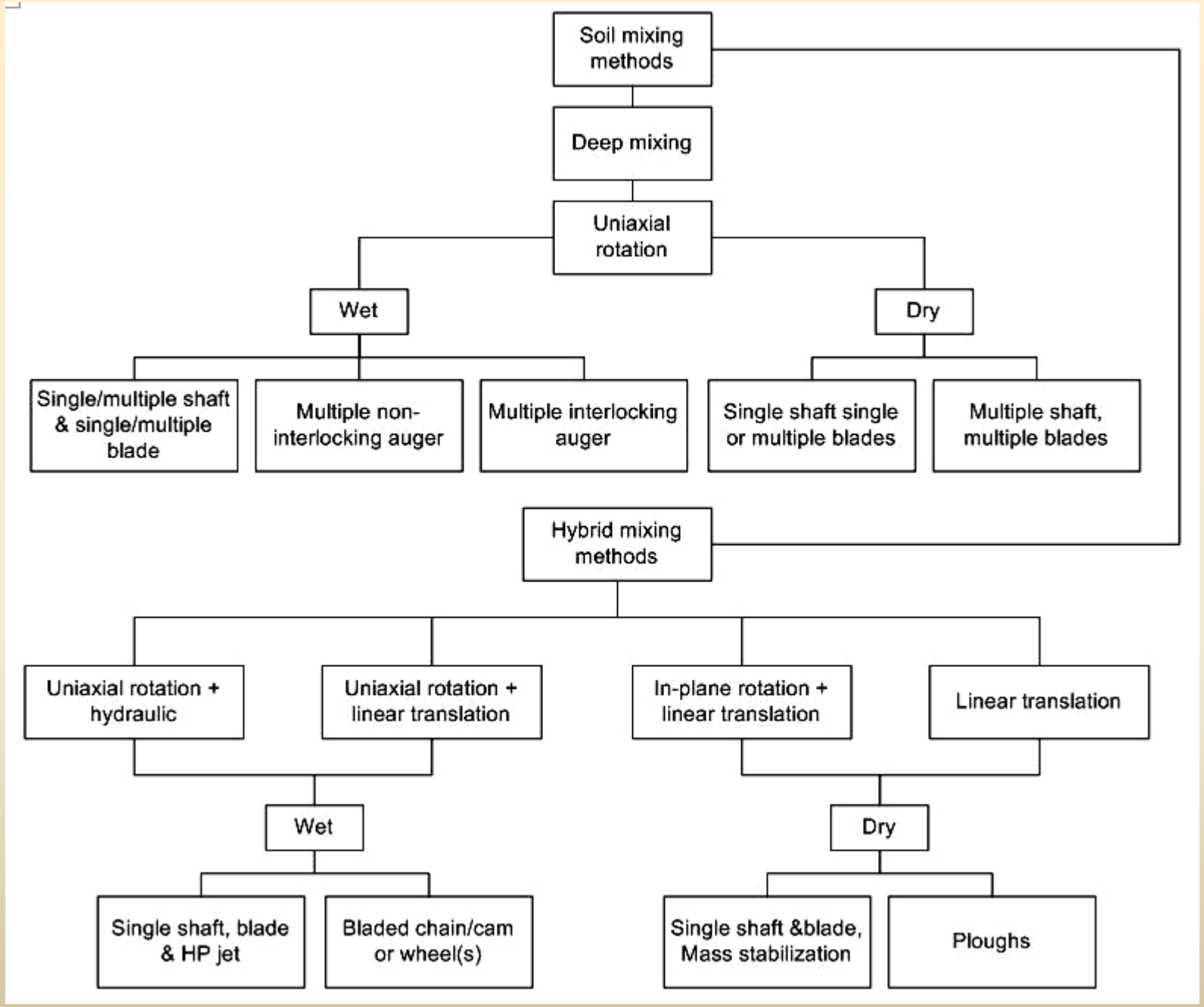


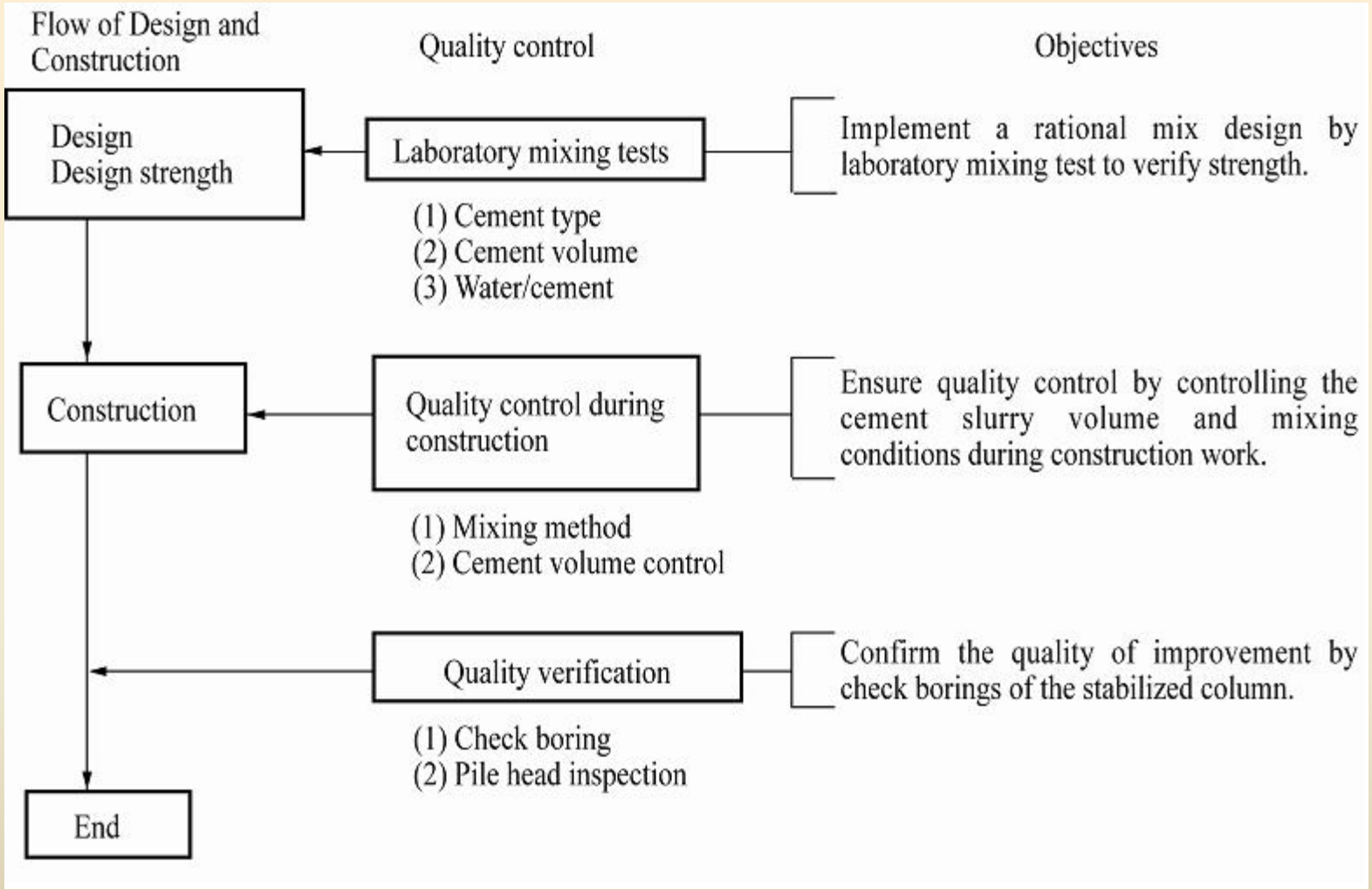
Cross section of coal berm

- The study showed that the costs were competitive compared to conventional retaining walls
- The ease and the ability to shape a soil cement in a variety of configurations to meet the project demands was useful.

Deep mixing methods

Mixing soil with cement, lime or other binders has been a common soil stabilization method. For fills, the mixing can be done before placement with or without compactions.
Most frequently, soils are mixed in-situ with cement and/or lime using a specially made machine. This method was developed in Japan and in the Scandinavian countries independently in the 1970s. The method has been called in different names, but commonly referred to as deep cement mixing (DCM or DMM).


Soil mixing methods
Deep mixing
Uniaxial rotation
Wet
Dry
Single/multiple shaft & single/multiple blade
Multiple non-interlocking auger
Multiple interlocking auger
Single shaft single or multiple blades
Multiple shaft, multiple blades
Hybrid mixing methods
Uniaxial rotation + hydraulic
Uniaxial rotation + linear translation
In-plane rotation + linear translation
Linear translation
Wet
Dry
Single shaft, blade & HP jet
Bladed chain/cam or wheel(s)
Single shaft &blade, Mass stabilization
Ploughs


Flow of Design and Construction
Quality control
Objectives
Design
Design strength
Laboratory mixing tests
Implement a rational mix design by laboratory mixing test to verify strength.
(1) Cement type
(2) Cement volume
(3) Water/cement
Construction
Quality control during construction
Ensure quality control by controlling the cement slurry volume and mixing conditions during construction work.
(1) Mixing method
(2) Cement volume control
Quality verification
Confirm the quality of improvement by check borings of the stabilized column.
(1) Check boring
(2) Pile head inspection
End

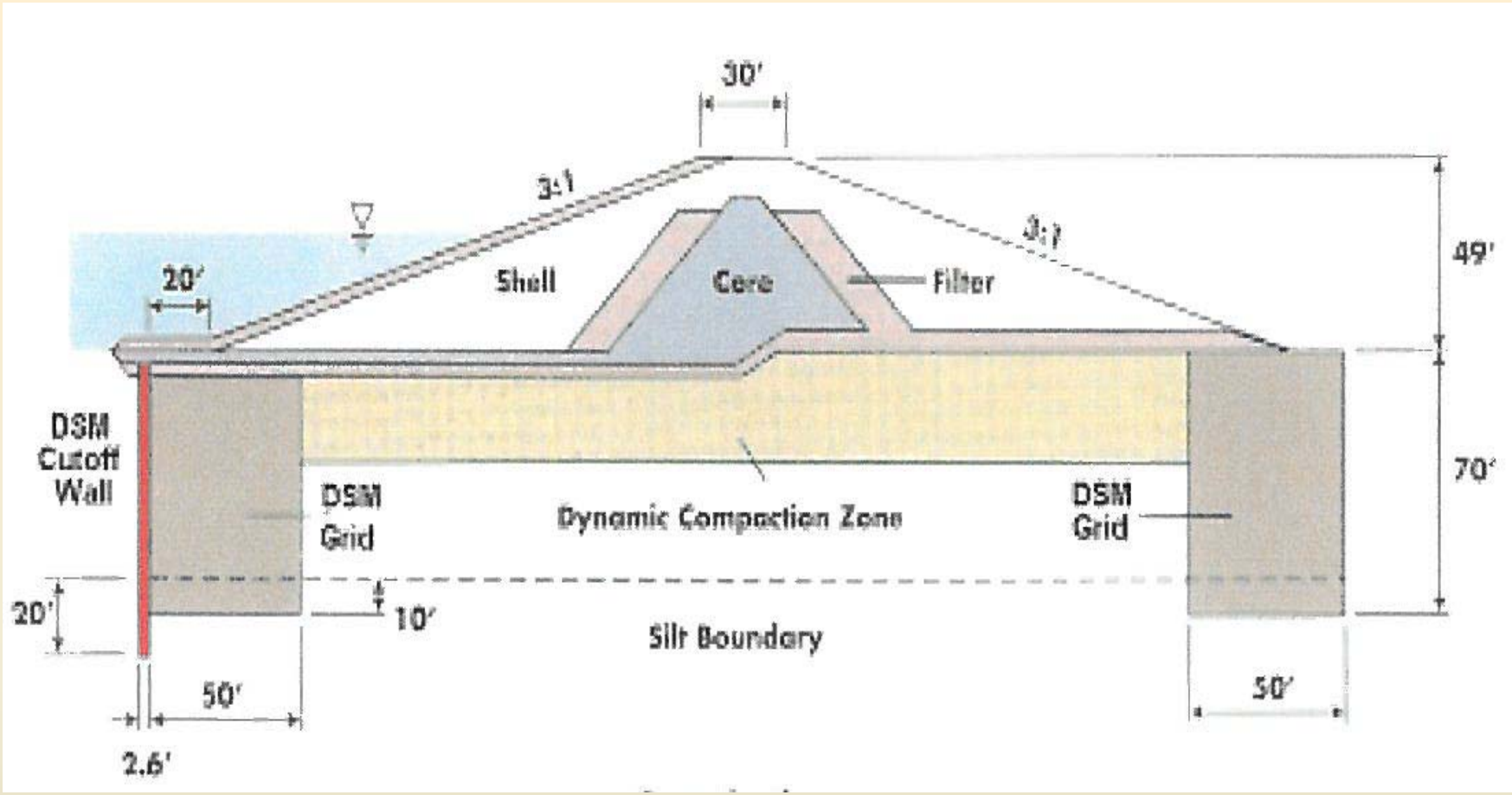
Case study:

Deep soil mixing at the Jackson Lake Dam

- The Jackson Lake Dam was constructed in 1917 in Wyoming.
- The dam was a hydraulic fill placed on a natural alluvium and outwash foundation.
- The Bureau of Reclamation determined that the dam and its foundation would be susceptible to liquefaction and failure during a potential earthquake.
- After considering a number of options, the Bureau selected deep soil mixing (DSM) as the method to improve the subsoil's and to install an upstream cut-off wall.

Results obtained from the testing program showed that:

- ❖DSM samples continue to increase in strength for at least 112 days after placement.
- ❖Water cement ratio is the key determining factor in final strength, even more important than cement content.
- ❖Laboratory results run before the project conservatively predicted field results.
- ❖Wet mix samples generally have lower strengths than cores taken after the column set.



Cross section of work plan

Conclusions:

- Shear strength was determined using triaxial and direct shear test and results showed that there was a gain in strength by implementing DSM technique.
- High quality and high strength columns can be constructed using this technique.
- At the Jackson Lake project, deep soil mixing provided an economical, reliable way of satisfying a difficult set of technical parameters and meeting a tight project work schedule.

References

Hausmann M R (1984) Engineering principles of Ground Modification.
Schafer et al (1997) Ground Improvement, Ground Reinforcement, and Ground Treatment- Developments; 1987-1997, Geotechnical Special Publication; No 69.
Jian Chu (2009) Construction Processes, State of the Art Report, ICSMGE, Alexandria, Egypt.