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THE UNIFIED PLOT APPROACH FOR ASSESSING INTERNAL EROSION – A CASE STUDY OF THE GRUNDSJÖN DAM SINKHOLE EVENT [*]

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1. INTRODUCTION

An embankment dam normally comprises several zoned fill materials, including a core, one or more filters and support fills, all of which are necessary for the satisfactory performance of the dam. Although nearly impervious, the core permits some seepage from the dissipation of the reservoir's hydraulic head acting on the upstream face of the dam. In adverse circumstances, the seepage concentrates into leakage paths which may cause erosion within the zones of the dam. Internal erosion occurs when soil particles migrate through the constrictions of a zoned soil or into a neighbouring zone. Surpassed only by overtopping, internal erosion is a major cause for the failure of embankment dams [1]. Four mechanisms associated with the initiation of internal erosion are recognised by ICOLD [1], namely i) concentrated leak erosion, ii) backward erosion, iii) contact erosion and iv) suffusion. Suffusion, due to internal instability, erodes free fines inside of a soil and may cause a property change; in contrast, backward erosion

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[*] *Approche par scénario visant à évaluer l'érosion interne – Étude de cas du trou d'affaissement du barrage de Grundsjön*

usually originates from an incompatible base-filter interface eroding progressively backwards. The core is protected from internal erosion, albeit indirectly, by a filter. An ineffective filter is unable to arrest an initiated erosion process, thus the continuation of internal erosion is generally dependent on the filter action of the zone located downstream of its base.

The literature offers several methods to evaluate the susceptibility of a material to initiation and continuation of internal erosion [1]. In general, the methods are empirically developed from laboratory studies with little or no systematic comparison to field experience. However, in a study of empirical methods for the assessment of filters in dams, Rönnqvist et al [2] assessed the filter gradations compiled in a database of 80 existing embankment dams that includes 23 dams which are reported to have experienced some form of internal erosion. The methods examined were those of Kenney and Lau [3, 4] with its adaption by Li and Fannin [5], and that of Burenkova [6] with its adaptation by Wan and Fell [7], as well as an alternative method by Wan and Fell [8]. Furthermore, potential core-filter incompatibility was assessed by using the method of Foster and Fell [9]. The comparative analysis of Rönnqvist et al [2] found a relation between attributes of the filter gradation and the probable occurrence of internal erosion in a dam. The finding suggests a unified plot of internal instability and a filter's capacity for soil retention may be useful as a screening tool for internal erosion susceptibility in engineering practice.

This paper describes the unified plot approach for assessing internal erosion susceptibility of existing dams. Thereafter, it reports a case study of the Swedish Grundsjön dam and an evaluation of its sinkhole event in 1990 using the unified plot approach.

2. THE UNIFIED PLOT APPROACH

A database was compiled by Rönnqvist [10] comprising 80 embankment dams commissioned in the period 1941 to 1993, with heights in the general range 10 to 125 m. The database includes information on the core and filter zone of each dam, and it comprises dams in Sweden (64), Canada (4), Norway (4), the USA (3), Finland (2), Australia (2) and New Zealand (1). Common to all of the dams is a core material of glacial till, with non-plastic or low-plasticity fines, in contact with a granular filter. By the use of performance monitoring data from published and, in some cases, unpublished reports, 23 of the dams were identified as earth structures in which a probable occurrence of internal erosion has been documented. For these dams, the performance records reveal one or more incidents believed indicative of internal erosion (e.g., high piezometric water levels in the downstream filter, increased seepage flow, muddy discharge, and in many cases sinkhole activity). They are categorised as dams with "probable occurrence of internal erosion" (denoted by capital letters in Fig. 1 and described in detail in [2]). Thus, 57 are dams with no record of any deficiency, else have exhibited a deficiency that cannot be attributed with any reasonable confidence to seepage-related erosion phenomena (categorised as dams with “no indications to-date of internal erosion” in Fig. 1).

Kenney and Lau [3, 4] proposed that the potential for internal stability be evaluated from a shape analysis of the gradation curve over a designated portion of its finer end. The finer grains in such a soil are smaller than available void space in the coarse fraction allowing for erodible free fines in the under-filled voids of the coarser fraction. The comparative analysis of Rönnqvist et al [2] of available empirical criteria for internal stability assessment indicated that the approach by Kenney-Lau was relatively more successful in identifying the dams with probable occurrence of internal erosion (Fig. 1). Furthermore, the examination of the database of 80 dams revealed that the greater the value of D_{15max}, the more likely a dam in the database has a probable occurrence of internal erosion [2].

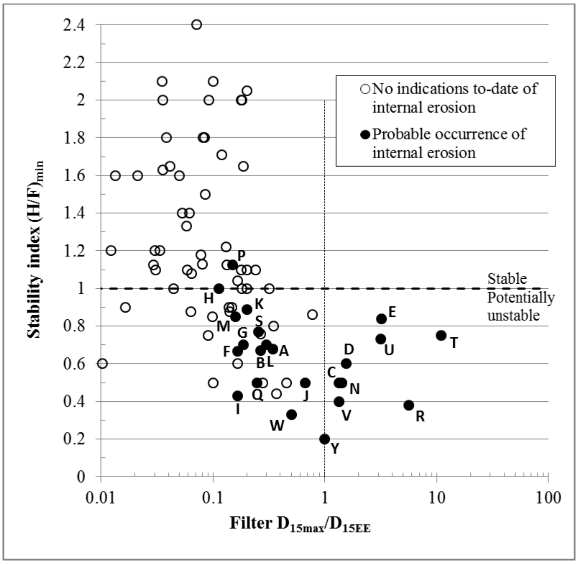


Fig. 1
Dimensionless unified plot of the relation between stability index of the filter gradation and dam-specific ratios for base soil retention D_{15max}/D_{15EE} [2]
Scénario adimensionnel de la relation entre l'indice de stabilité correspondant à la granulométrie du filtre et les coefficients - spécifiques aux barrages - de rétention du sol de base

Analysis of the soil retention capacity of a filter using the method of Foster and Fell [9] indicates that the Foster-Fell empirical boundaries for base soil retention by a filter (i.e., a No Erosion (NE) boundary, an Excessive Erosion (EE) boundary; and, a Continuing Erosion (CE) boundary) correlate well with the inferred probable occurrence of internal erosion (Fig. 1). The range between the NE and EE boundaries is termed, herein, the Some Erosion zone of base soil retention. By taking all the available gradation curves for the filter of the dams into account, gradation analysis established the most vulnerable gradation curve in terms of stability indices H/F_{min} and D_{15max}, yielding one data point per dam. Furthermore, the dimensionless plot is established by using the dam-specific EE boundary to calculate the ratio D_{15max}/D_{15EE} (Fig. 1). Thus, combining the stability index $(H/F)_{min} < 1$ of Kenney and Lau [3, 4] with the soil retention capacity of a filter (by using the filter boundaries proposed by Foster and Fell [9]), yields a significant improvement in the identification of dams that exhibit deficiencies from internal erosion, and thereby encourages use of the unified plot (Fig. 1) as a screening tool for internal erosion susceptibility in engineering practice. The dam denoted by “J” in Rönnqvist et al [2], as illustrated in Fig. 1, is the most vulnerable data point for the Grundsjön dam, which will be studied in detail in the following.

3. THE GRUNDSJÖN DAM AND SINKHOLE EVENT

3.1. THE SINKHOLE EVENT AND INVESTIGATIONS

In September 1990, 18 years after commissioning, a crater-like depression was discovered on the upstream edge of the crest of the Grundsjön Connecting dam (Fig. 2). The depression measured 0.4 x 0.5 m on the surface, and closer examination revealed it to extend approximately 1.6 m vertically into the dam body. It was aligned with the upstream face of the core, and thus possibly a sinkhole due to internal erosion [11]. In a first phase of examination in the fall of 1990, immediately after the discovery of the sinkhole, the crest of the dam was removed exposing the crest of the core in the area of the sinkhole. Although these initial test pits revealed relatively little about the extent of the damage, the exploratory penetration tests conducted from the crest of the core, as well as falling-head tests carried out in the piezometers, provided more information; the core soil was loose locally and exhibited a high take of water during the infiltration tests. Furthermore, the piezometric readings from the standpipes in the core showed pore pressure levels higher than theoretically expected. These findings indicated that the core was, indeed, damaged, possibly by internal erosion, but additional investigations were needed to clarify the cause of the sinkhole and to ensure a safe resumed operation of the reservoir. Thus, a second phase of examination was undertaken in the spring of 1991 which involved a complete uncovering of the core and filter over a length of 60 m. Excavation was carried out in stages of 1 m lifts and at the lowest it reached down to +644m, 13 m below the dam crest, completely exposing the filter and core (Fig. 3). Visual observations are shown in Fig. 3. Several signs believed indicative of internal erosion were observed, most notably the actual sinkhole, cavities in the core, wet zones, core soils devoid of fines and the presence of a leakage path through the core (observation 5, Fig. 3). Furthermore, there were observations indicative of the continuation of erosion, e.g., filters washed out of fines (Fig. 3) as well as probable contributing causes to the process (pockets of coarse filter of cobbles possibly a consequence of segregation during placement). The dam was carefully rebuilt in 1991, and was provided with an improved drainage system as well as the implementation of an extensive monitoring program of instrumentation [11, 12].

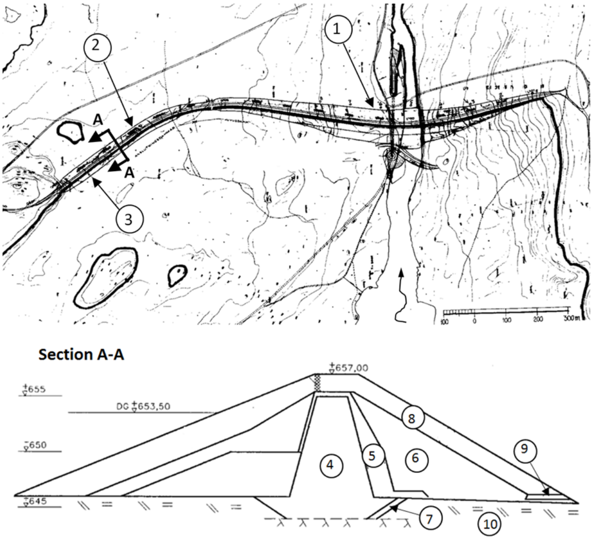
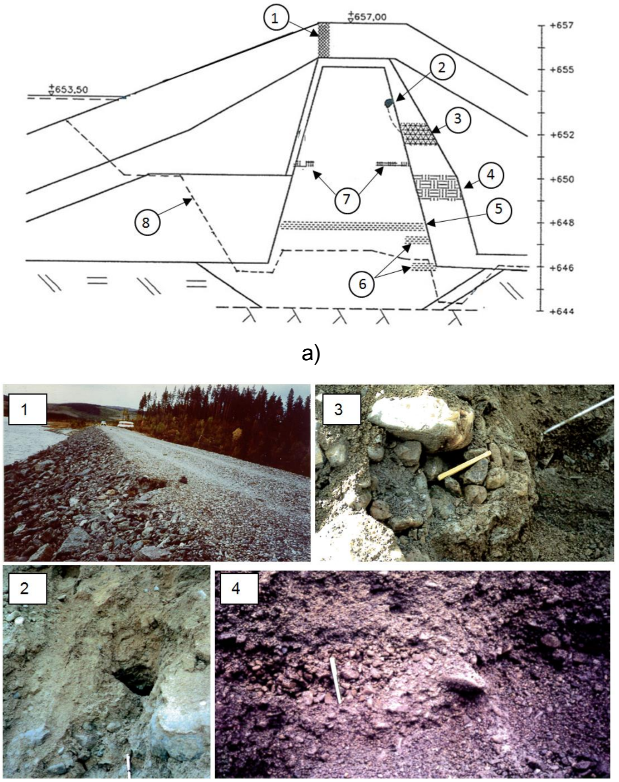


Fig. 2

The Grundsjön dam (in plan view) and connecting dam (in cross-section)
Le barrage de Grundsjön (vue en plan) et le barrage de liaison (vue en coupe)

1) Main dam	*1) Barrage principal*
2) Connecting dam	*2) Barrage de liaison*
3) Sinkhole location	*3) Emplacement du trou d’affaissement*
4) Core of glacial till	*4) Noyau en matériau morainique*
5) Filter of sand and gravel	*5) Filtre de sable et gravier*
6) Shell of gravel	*6) Coque de gravier*
7) Transition zone of gravel	*7) Zone de transition en gravier*
8) Shoulder of cobbles and stones	*8) Recharge en galets et pierres*
9) Transition zone of gravel	*9) Zone de transition en gravier*
10) Foundation of glacial till	*10) Fondation en matériau morainique*



a)

b)

Fig. 3
The excavation of the core in 1991 of the Grundsjön dam with a) observations and b) photo evidence (adapted after [11, 12])
Excavation du noyau du barrage de Grundsjön en 1991 avec a) observations et b) preuves photographiques (selon [11, 12])

1) Sinkhole	*1) Trou d'affaissement*
2) Large cavity in the core	*2) Grande cavité dans le noyau*
3) Fines washed out of filter with evidence of core fines in fill, and pockets of cobbles	*3) Matériaux fins du filtre lessivés avec présence de matériaux fins du noyau dans le remblai, et galets*
4) Fines washed out of filter	*4) Matériaux fins du filtre lessivés*
5) Fines washed out of core and leakage path	*5) Matériaux fins du noyau lessivés et chemins d'infiltration*
6) Wet zones	*6) Zones humides*
7) Small cavities in the core	*7) Petites cavités dans le noyau*
8) Excavation limit	*8) Limite d'excavation*

3.2. DAM DESIGN AND CONSTRUCTION

The Grundsjön dam is located on the Ljusnan River in Sweden and put into service in 1972. The embankment dams comprise the 1200 m long and 43 m high Main dam, and the 600 m long and 15 m high Connecting dam, as shown on the layout in Fig. 2, together with location of the sinkhole and a cross-section of the Connecting dam which suffered the sinkhole. The core zone of the embankment dams was founded on bedrock through a fully penetrating cut-off trench, whereas the shoulders were placed on natural soils of morainic deposits (Fig. 2). The bedrock was deep-grouted in one centrally-aligned to the core injection row, with additional rows of surface grouting added where needed.

The core material (zone 4, Fig. 2) consists of glacial till which, according to specifications, should have a maximum of 85 % < 2 mm and 15 to 50 % < 0.075 mm (fines content) when regraded to a D_{max} = 64 mm [11]. Although not tested, the fines are assumed non-plastic. Larger stones were removed directly at the borrow area, and further sorting was done by sieve buckets on site. The core soil was spread by blading out piles of glacial till dumped in the vicinity of its intended final location, and compacted was done at optimum water content of 7 % [11]. Achieved dry densities in-situ averaged at 94 % relative the maximum dry densities from Modified Proctor tests (i.e., 2.1 to 2.2 ton/m^3); however, reports show occasional relative densities as low as 88 % [11].

Against bedrock, a 0.5 m thick layer of contact glacial till (D_{max} < 64 mm) was placed in lifts of 0.2 m that were compacted with vibratory plates. Above the contact layer, the glacial till was initially placed in 0.4 m lifts (with D_{max} < 250 mm) and compacted with six passes by the 9.0 T rollers. Subsequently, field tests showed that satisfactory compaction was obtained at higher lifts, thus the lifts were increased to 0.75 m (D_{max} < 400 mm) and the compaction effort was increased to eight passes by the 9.0 T rollers [11].

The downstream filter (zone 5, Fig. 2) is composed of sand and gravel, which according to specifications, should have Dmax < 50 mm, a maximum of 10 % < 0.25 mm and 30 % < 4 mm < 70 % [11]. The filter was sorted with sieve buckets to D_{max} = 64 mm; processing and handling made it segregate readily, requiring special attention during placing. The filter was spread, placed and compacted similarly to the core specifications. The shell of gravel (zone 6, Fig. 2) was spread by blading out to 1 m thick layers, and compacted with eight passes by the 9.0 T rollers, with a D_{max} = 400 mm permitted. The erosion control below the core is provided by the transition zone of gravel between the core and the downstream face of the trench (zone 7, Fig. 2). This material was dumped from the trench crest without any particular compaction, with a D_{max} = 300 mm.

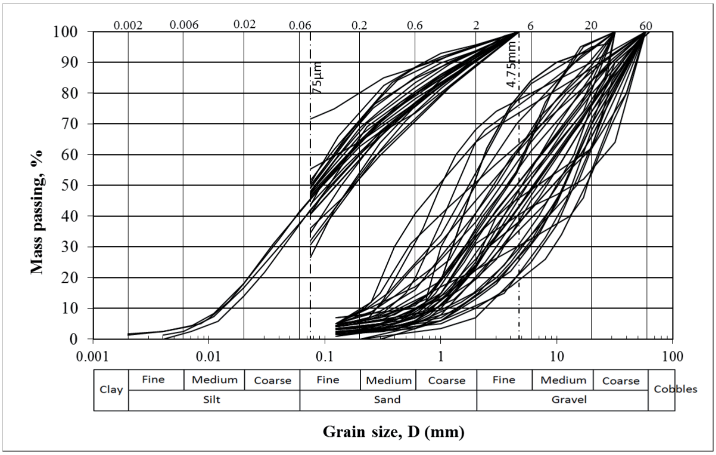


Fig. 4
Envelope of core gradations (< 4.75 mm) and as-placed filter gradations of the Grundsjön dam
Enveloppe de granulométrie du noyau (< 4,75 mm) et du filtre en place sur le barrage de Grundsjön

3.3. ASSUMED CAUSE FOR THE SINKHOLE AS PER 1991

The probable cause of the sinkhole as postulated at the time was the combined effect of a series of events over a long period of time as follows: i) wetting settlement of the lower part of the core during the first impoundment that creates weak-zones at the interface to the arched upper part of the core, ii) hydraulic fracturing and leakage through weak-zones and ineffective downstream filter, iii) the formation of transverse zones through the core from backward erosion causing significant leakage, and iv) the collapse of the core and subsequent sinkhole formation [11, 13].

4. APPLICATION OF THE UNIFIED PLOT APPROACH

The gradations of the core and filter gradations are presented in Fig. 4. They comprise 43 filter gradations and 27 core gradations taken from construction records [11]. The core soil is a glacial till and when regraded on the #4 sieve (i.e., 4.75 mm), as shown in Fig. 4, it has about 30 to 50 % < 0.075 mm (i.e., fines content); less than 2 % < 0.002 mm (i.e., clay-size); and a d_{85} of 0.3 to 1.0 mm. The filter is a sandy gravel with $0.3 \leq D_{15} \leq 3.5$ mm and $D_{max} = 64$ mm.

There are no records as to whether larger D_{max} were permitted in the filter, and although the specifications stipulated 50 mm, forensic photo evidence indicates that coarser fractions than this were used (Fig. 3).

Applying the Kenney and Lau criterion [3, 4], and the Li and Fannin adaptation [5], Fig. 5 shows the H:F shape curves for the 43 filter gradations. Extracting the stability index ($(H/F)_{min}$) from the H:F shape curves, i.e., the smallest value of H/F in the evaluation range $0 < F \leq 20$ %, reveals that 16 of the 43 gradations (37 %) are potentially unstable (i.e., $(H/F)_{min} < 1$) with a lowest stability index $(H/F)_{min}$ of 0.43. Many of the gradations are unstable on their finer end (Fig. 6). The Grundsjön dam data for all 43 filter gradations are thus superimposed over the Rönnqvist et al [2] database which comprises the single-most vulnerable data point for each dam. Similarly, the method of Wan and Fell [7], which evaluates internal instability from a characteristic value for the slope of the coarser fraction (D_{90}/D_{60}) and the overall slope of the gradation curve (D_{90}/D_{15}), establishes that 18 of the gradations are unstable, with the highest probability of 90 % for one gradation (Fig. 7). The Foster and Fell filter boundaries [9] analysis shows, moreover, that the dam-specific NE boundary is 0.7 mm for the Grundsjön dam (i.e., Group 2A base soil for which the fines content is 35 to 85 % of base soil passing the No. 4 (4.75 mm) sieve), the EE boundary is approximately 4.5 mm and the CE boundary is 18 mm (i.e., $D_{15} > 9\ d_{95}$ after [14]).

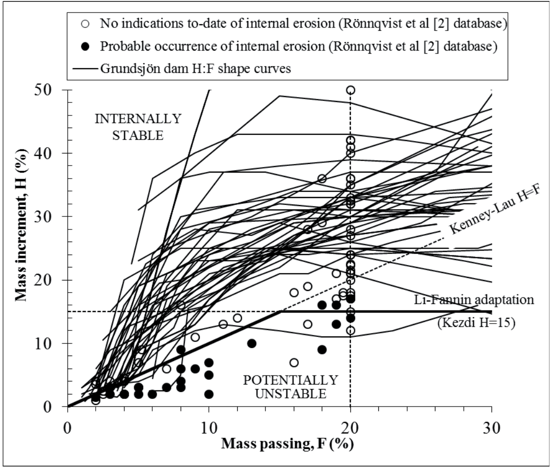


Fig. 5

H:F shape curves of Grundsjön dam filter gradations superimposed over Rönnqvist *et al* [2] database

Courbes H:F de granulométrie du filtre du barrage de Grundsjön superposées à la base de données Rönnqvist et al [2]

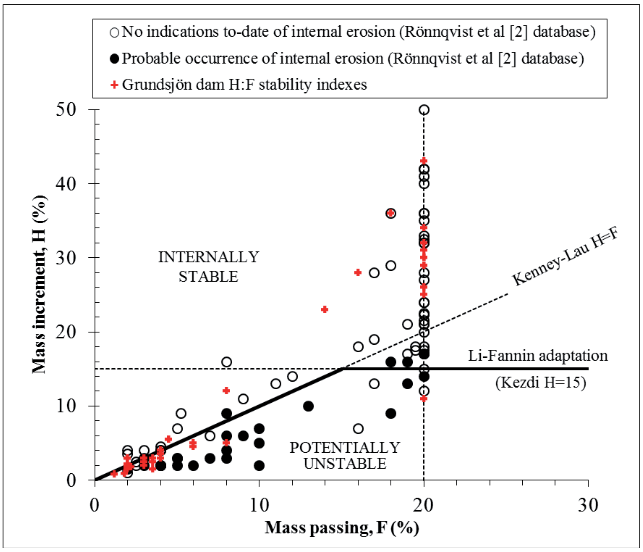


Fig. 6

Stability indexes of Grundsjön dam filter gradations superimposed over Rönnqvist *et al* [2] database

Indices de stabilité des types de granulométrie du filtre du barrage de Grundsjön superposés à la base de données Rönnqvist et al [2]

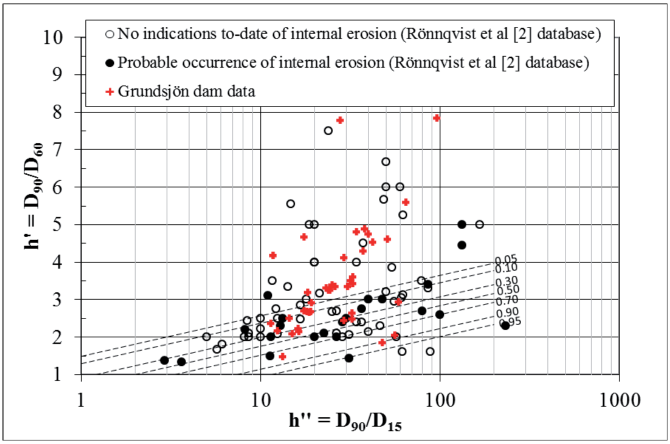


Fig. 7

Probability of internal instability of the filter gradations of the Grundsjön dam superimposed over Rönnqvist *et al* [2] database

Probabilité d'instabilité interne des types de granulométrie du filtre du barrage de Grundsjön superposés à la base de données Rönnqvist et al [2]

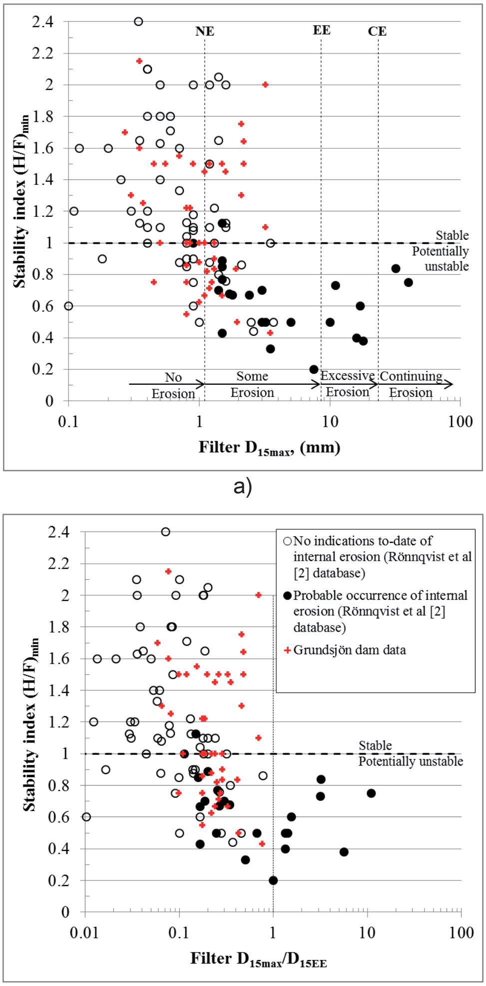
Analysis of the unified plot (Fig. 8a) shows that a considerable number of gradations locate in the No Erosion and internally stable zone, but there are gradations on the coarser end of the envelope that clearly plot in the Some erosion and internally unstable zone. This zone is where many dams with probable occurrence of internal erosion are found to plot. In the dimensionless unified plot (Fig. 8b), on a dam-specific basis, the data of the Grundsjön dam are plotted in relation to its EE boundary of 4.5 mm: the majority of gradations plot in the Some erosion zone (which is located in the range between the NE and EE boundaries), which according to the method of Foster and Fell [9] would make it equally likely that the filter will seal with Some erosion as with Large erosion in the case of a concentrated leak through the core.

4.1. DISCUSSION

Strictly, from an assessment of the filter gradations reported in the construction records, the filter satisfies the EE boundary (*ergo* the CE boundary). According to Foster and Fell [9] that would make a scenario with no sealing of the filter unlikely and a continuing erosion process highly unlikely as the filter appears finer-grained than one which would allow unrestricted erosion (Fig. 8a and Fig. 8b). However, taking into account that the filter is potentially unstable (Fig. 6 and Fig. 7), it may be coarser in-situ than expected from the reported as-placed gradations. In an internally unstable soil, the finer fraction is susceptible to erosion.

According to ICOLD [1] the amount of finer fraction can be located by identifying the point of inflection of a gradation where there is a change in slope of the sieve curve occurring at the transition from the coarse fraction to the finer fraction. In addition, Wan and Fell [8] proposed a way of estimating the shape of the suffused gradation by assuming that 50 % of the finer fraction of the unstable soil is lost and, in a conservative assessment, a 100 % loss.

Taking the ICOLD [1] and Wan and Fell [8] approach into account, in terms of finer fraction and its loss through the action of suffusion, the resultant gradation for two construction gradations (i.e., #20 and #28) deemed representative of the Grundsjön dam are shown in Fig. 9. Accordingly, assuming a 50 % loss of the finer fraction yields an effective D_{15} of approximately 6 mm, and the conservative approach of assuming a 100 % loss yields a D_{15} of 7 to 18 mm. Considering the dam-specific EE boundary of 4.5 mm the two selected construction gradations would exceed it. In support, forensic photo evidence (Fig. 3) indicates that the filter was indeed washed out (suffused).



a)

b)

Fig. 8

Unified plot approach with data points from the analysis of Grundsjön dam superimposed over Rönnqvist *et al* [2] data base

Approche par scénario avec des points à partir de l'analyse du barrage de Grundsjön superposée à la base de données Rönnqvist et al [2]

a) Unified plot with average values of NE, EE and CE.

b) Dimensionless unified plot for D_{15max}/D_{15EE}

a) Scénario avec les valeurs moyennes de NE, EE et CE.

b) Scénario adimensionnel pour D_{15max}/D_{15EE}

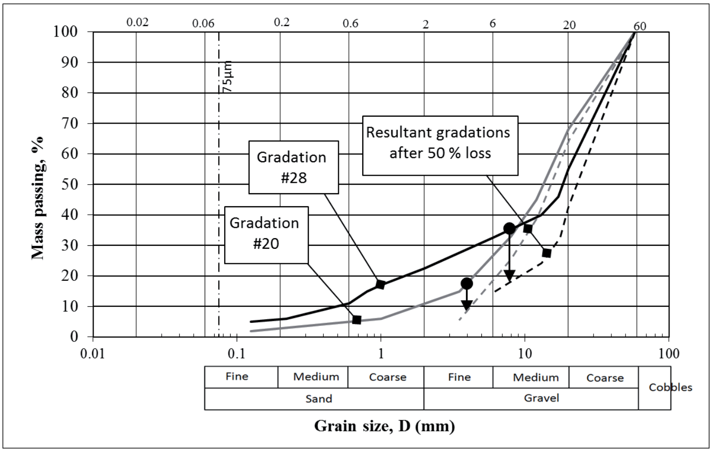


Fig. 9

Selected filter gradations of the Grundsjön dam that are potentially unstable and corresponding filter assuming a 50 % loss of finer fraction

Granulométries sélectionnées du barrage de Grundsjön potentiellement instables et filtre correspondant supposant une perte de 50 % de la fraction la plus fine

It has been postulated that contributing factors to the internal erosion process, both from the design conditions and also from the technical specifications of materials and procedures, are as follows:

- Potential wetting settlement due to dry compaction at or below optimum water content causing arching and differential settlements.
- An increased lift thickness to 0.75 m, larger D_{max} of 400 mm, and moderate compaction.
- Segregation issues in terms of the filter during handling as reported at the time of construction [11].

The theory put forward by Eurenius and Sjödin [11] as to the cause of the sinkhole at the time of the incident involved the formation of concentrated leaks (by settlements, arching and hydraulic fracturing), and the presence of an inadequate filter which allowed backward erosion through the core, causing unacceptable leakage and eventually leading to the formation of the sinkhole.

This review supports the previous postulated cause of the sinkhole event. Based on the many observations linking the incident to internal erosion, clearly the process which ultimately leads up the sinkhole event is the result of several interplaying internal erosion mechanisms; suffusion, concentrated leak erosion and insufficient capacity of the filter for base soil retention (i.e., backward erosion). This supports the use of the unified plot that combines the assessment of two key attributes of a filter; the Grundsjön dam plots where dams with probable occurrence typically plot, i.e., potential internal instability of the filter and inability to arrest an initiated internal erosion process.

5. CONCLUSIONS

The unified plot approach [2] combines two empirical methods with experience from performance of existing dams; internal instability and incapacity for soil retention of filters correlate well with dams that exhibit deficiencies that can be reasonably attributed to internal erosion.

Application of the unified plot approach provides a possible explanation to the 1990 sinkhole event in the case study of the Swedish Grundsjön dam. The filter is potentially internally unstable, and filter criteria indicate that the base and filter interface is incompatible. These aspects when combined suggest a vulnerability to the initiation of internal erosion and its continuation given that the filter is potentially inconstant in the long-term (due to filter suffusion). Photo evidence supports this as filter suffusion indeed had occurred and cavities and wet zones of the core provide evidence for the occurrence of backward erosion, and furthermore, the sinkhole formation is the result of a late-stage internal erosion process which probably had reached the continuation phase.

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NOTATION

d	grain size of the base soil (mm)
D	grain size of the filter (mm)
F	mass passing at grain size D (%)
H	mass increment between D and 4D (%)
$(H/F)_{min}$	stability index, defined by the smallest value of H/F, for $0 < F \leq 20$ % in soil with a widely-graded coarse fraction

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SUMMARY

The unified plot approach combines two attributes of a filter gradation, namely its potential for internal instability and its capacity for soil retention. Comparison to the performance of 80 existing embankment dams that includes 23 dams which are reported to have experienced some form of internal erosion, these attributes of the filter have been found to correlate with deficiencies related to internal erosion. Thus, in engineering practice, the unified plot may serve as a screening tool for internal erosion susceptibility.

The Grundsjön dam, located on the river Ljusnan in Sweden, suffered a sinkhole event in 1990, 18 years after commissioning. In depth examination of the damaged stretch of the dam conducted in 1990 to 1991 revealed that internal erosion had indeed occurred; signs e.g., cavities in the core and filter devoid of fines suggest the process had initiated and been allowed to continue to the point that a sinkhole formed on the crest.

Analysis of 43 as-placed filter gradations extracted from the Grundsjön dam filter envelope indicates that the filter is potentially unstable, although, not excessively coarse in terms of base soil retention. These results, as seen separately, provide relatively little explanation as to why the filter ultimately was unable to arrest the internal erosion process. However, combined, in the framework of the unified plot, it is readily apparent that the Grundsjön dam filter gradations distribute where dams with probable occurrence of internal erosion characteristically plot. Thus, the unified plot provides a plausible explanation for the internal erosion process that occurred. Indeed, reverse engineering the potential internal instability of the coarse filter gradation indicates that once changed by suffusion due to internal instability it potentially becomes a filter permitting excessive erosion.

The Grundsjön dam was carefully rebuilt in 1991 and was provided with an improved drainage system as well as the implementation of an extensive monitoring program of instrumentation, and has since operated satisfactorily.

RÉSUMÉ

L’approche par scénario combine deux caractéristiques de la granulométrie du filtre : son instabilité interne potentielle et sa capacité de rétention des sols. En comparant le comportement de 80 barrages en remblai existants, parmi lesquels 23 barrages ayant subi une forme d’érosion interne, ces caractéristiques du filtre se sont avérées avoir une corrélation avec les altérations liées à l’érosion interne. Ainsi, en matière de génie civil, le scénario peut être utilisé comme outil de dépistage d’une érosion interne potentielle.

Le barrage de Grundsjön, situé sur le fleuve Ljusnan, en Suède, a subi un trou d’affaissement en 1990, 18 ans après sa mise en service. L’examen en profondeur des parties endommagées du barrage, effectué de 1990 à 1991, a révélé une érosion interne ; des signes, tels que des cavités dans le noyau et l’élimination et matériaux fins dans le filtre, indiquent vraisemblablement que le processus a été initié et a pu se poursuivre jusqu’à former un trou d’affaissement.

L’analyse de 43 types de granulométrie dans le filtre en place, extraits de l’enveloppe du filtre du barrage de Grundsjön, indique que le filtre est potentiellement instable, bien qu’il ne doit pas excessivement grossier au regard de la rétention du sol de base. Vus séparément, ces résultats expliquent difficilement pourquoi le filtre a été au final incapable d’arrêter le processus d’érosion interne. En revanche, combinés dans le cadre d’un scénario global, il est évident que la distribution de la distribution granulométrique du filtre du barrage de Grundsjön indique les emplacements où une érosion interne risque fortement de se produire. Ainsi, le scénario donne une explication plausible du processus d’érosion interne qui s’est produit. En effet, l’ingénierie inverse appliquée à l’instabilité interne potentielle de la granulométrie du filtre grossier montre qu’une fois modifié par suffusion en raison de l’instabilité interne, le filtre permet une érosion excessive.

Le barrage de Grundsjön a été soigneusement reconstruit en 1991 avec un système de drainage plus performant et accompagné de la mise en place d’un large programme de surveillance des instruments, et fonctionne depuis de manière satisfaisante.