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MATHEMATICAL MODELS USED FOR MODELING COMPACTION PROCESSES RESULTING FROM SOIL MECHANICS

BY

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Abstract. The analysis of the issue of landfill compaction has aroused numerous reactions over the last thirty years. Therefore, one should not be in the least surprised of the impressive number of laws and applications found in literature, which are rather aimed at modeling landfill compaction than at controlling this phenomenon.

In this paper, we intend to synthesize the mathematical models used for modeling different compaction processes resulting from soil mechanics. The models were selected based on assumptions and principles on which their authors rely when developing their own methods. The laws shown in literature are described by various authors in their own ways.

In order to facilitate their comparison with the observance of numerous criteria, it is important to show the findings of the research conducted, based on a particular type of chart. It includes four parts (assumptions, model, parameters and assessment) and it allows better determination of the advantages and disadvantages of each model.

Keywords: mathematical models; soils mechanics; analysis.

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1. Introduction

The mechanisms responsible for landfill compaction are more numerous and much more complex than those affecting soil compaction. The structure of any refuse collection, which is very heterogeneous, is fundamentally altered over time due to the amount of biodegradable organic matter and to the impressive volumes of empty spaces present in the landfill.

Manassero (1996) quoted by Olivier (2003) that the progress of the waste compaction process includes 5 stages:

a) mechanical compression associated with the deformation, distortion, flexion, reorientation and crushing of elements (duration: a few minutes);

b) reorganization accompanied by volume reduction due to the migration of small elements in the empty spaces found between the bigger elements (duration: 3 up to 5 hours);

c) consolidation and creep (duration: 2-3 months to 1 year);

d) compaction caused by organic matter decomposition (duration: 10 to 50 years);

e) decomposition of certain inorganic compounds due to corrosion and chemical reactions.

In the light of these stages, landfill compaction and compaction speed depend on several parameters that may interact:

i) type of waste (especially the percentage of organic matter);
ii) void ratio;
iii) volumetric weight and density;
iv) height of the refuse collection in the landfill;
v) compaction method (compaction energy, compaction degree, etc.);
vi) filling rate;
vii)conditions influencing biodegradable organic matter decomposition (temperature, atmospheric conditions, water concentration, leachate and biogas production, etc.).

The determination of all these parameters, their relative importance and evolutionary nature are the source of the main waste compaction estimation and modeling difficulties.

Analogies are possible based on the soil mechanics principles, in order to assess landfill compaction, since, despite the fact that the processes involved and the parameters that should be considered are much more numerous, the evolution laws ultimately have certain similarities.

2. Models Resulting from Soil Mechanics

This category includes methods that were developed as the groundwork for soil behavior modeling. Then, they were extended and adjusted to the “waste” material thanks to the analogies between the behavior of this matter and that of certain soils.

2.1. Sowers Model (1973)

A. Assumptions

1º The pile of waste should be in oedometric conditions (which means that lateral deformations are prevented). This assumption is valid for waste found away from the borders of the storage cells.

2º The pile of waste is considered to be a single pile built during one stage.

3º Analogy between waste and compressible organic soils.

4º The waste is considered to be saturated.

B. Model

Sowers defined waste compaction as a complex mechanism caused by a series of processes, which are physical and mechanical (generating particle reorientation, fine particle movement in empty spaces and collapse of big empty spaces), chemical (including corrosion, combustion and oxidation) and biological decomposition. As of that moment, the classification was approved by many different authors, such as Edil *et al.* (1990), Manassero *et al.* (1996) quoted by Olivier (2003) and Reddy (2006).

Further to an analogy between waste behavior and compressible organic soil behavior, Sowers suggests a waste compaction study model divided in three stages:

1º An instantaneous stage (it is not studied, since it is thought to occur immediately after load application).

2º A primary stage based on Terzaghi’s theory (1925), which occurs after a short time (generally, within a month after the landfill has been closed down) and during which the compaction is caused by mechanical actions.

3º A secondary stage, based on Buisman theory, which occurs on the long run and during which the compaction is caused by a combination of mechanical compression and physical-chemical and biological-chemical actions.

Primary compaction:

$$S_p = H_i C_{ce} \log \sigma_0^{'} + \frac{\Delta\sigma}{\sigma_0^{'}}.$$

Secondary compaction:

$$S_s = H_p C_{ae} \log \frac{t - t_0}{t_1 - t_0} \qquad \text{for } t > t_1.$$

This model has several advantages, such as its easy use given the small number of parameters required for its application. Nevertheless, we should mention that their determination may be difficult due to the heterogeneity of the “waste” material. Moreover, the model does not consider the history of refuse collection filling (which may be frustrating in case of a complex filling).

Finally, we may note that the distinction between the two consolidation phases may be complicated and also cause difficulties related to t_1 determination.

C. Parameters

t_1, H_i and H_p, e_0, decomposition conditions, organic matter percentage.

The altered primary compression index depends on the primary compression index (C_c) and on the initial void index (e_0).

$$C_{ce} = \frac{C_c}{1+e_0}.$$

Based on in situ measurements, Sowers also suggested a graph allowing the determination of a group containing the primary compression index values (Fig. 1). The author noted that they depend to the same extent on the initial void index and on the percentage of organic matter present in the waste.

Relying on Sowers' chart (Olivier, 2003) defines the primary compression index starting from the initial void index and an x coefficient which depends on the organic matter composition. This coefficient also considers the fact that the richer the waste in organic matter, the more compressible it is. Consequently, C_c will have a higher value.

$$C_c = xe_0,$$

where: x = 0.15 for waste poor in organic matter; x = 0.55 for waste rich in organic matter.

According to Gourc, the value of the altered primary compression index ranges between 0.15 and 0.30, yet the use of an average value of 0.22 is recommended, unless additional information is available (Verbrugge, 2000).

The secondary compression rate depends on the secondary compression index (C_a) and on the initial void index.

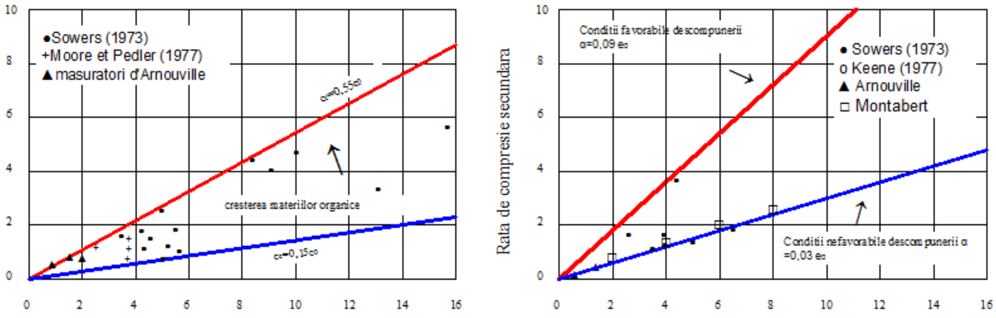
$$C_{ae} = \frac{C_a}{1+e_0}.$$

Sowers also suggested a group containing the secondary compression rate values (Fig. 1). It depends on the initial void index and on the decomposition conditions (in the presence or absence of oxygen).

Olivier (2003), also defines the secondary compression index as a function of the initial void index and of an x' coefficient intrinsic to the material.

$$C_a = xe_0,$$

where: x' = 0.03 for conditions that are less favorable for biodegradation; x' = = 0.09 for conditions that are the most favorable for biodegradation.



a *b*

Fig. 1 – *a* – Primary compression index depending on the initial void index;
b – Secondary compression rate depending on the initial void index
(Verbrugge, 2000).

D. Remarks

Many authors have tested this model in order to check its applicability. Many of their findings refer to secondary compaction representation (caused by both creep and biodegradation).

Chen (1974) also noted that the application of this model may be problematic in the case of unsaturated tailings, which include large empty spaces and particles, which may be the object of significant deformation due to creep and biodegradation phenomena and the properties of which vary over time.

Mitchell *et al*. (1995) have proven, based on their experiments, that Sowers' method may only be applied at the beginning of tailing filling (to be more exact, before the biodegradation process begins).

Nonetheless, further to laboratory tests, El-Fadel *et al*. (1999) have proven that this model has better applicability potential than the models suggested by Gibson *et al*. (1957), as it allows a more accurate description of secondary compaction phenomena. Moreover, it also has the advantage of not requiring a large number of parameters for its application.

Finally, Babu and Fox (1997) quoted by Olivier (2003) point out the fact that the representation of the compaction process as two separate stages is not realistic for a tailing.

E. Applications and adjustments

E.1. Application of the method to a site with unknown history

Often enough, the compaction of a site has to be studied after its closing down. This means that the data required for the use of Sowers's method are not known.

The purpose of the adjustment of Sowers' method is determined by C_{ae} based on three in situ measurements.

By applying Sowers' method, the following three ratios may be obtained:

$$s(t_m^0) = H_p C_{ae} \log\frac{t_m^0 - t_0}{t_1 - t_0};\quad s(t_m^1) = H_p C_{ae} \log\frac{t_m^1 - t_0}{t_1 - t_0};$$

$$s(t_m^2) = H_p C_{ae} \log\frac{t_m^2 - t_0}{t_1 - t_0}.$$

The equations are then combined two by two in order to obtain a three-equation system with three unknown variables (H_p, C_{ae} and t_0), which will be solved by successive approximations of t_0:

$$\Delta s_0^1 = H_p C_{ae} \log\frac{t_m^1 - t_0}{t_m^0 - t_0};\quad \Delta s_1^2 = H_p C_{ae} \log\frac{t_m^2 - t_0}{t_m^1 - t_0};$$

$$\Delta s_0^2 = H_p C_{ae} \log\frac{t_m^2 - t_0}{t_m^0 - t_0},$$

where: $\Delta s_0^1 = s(t_m^1) - s(t_m^0)$.

Nevertheless, this analysis is schematic. In order to achieve better C_{ae} approximation, a higher number of measurements is required over a longer period of time.

E.2. Method application based on the deformation rate

This application of Sowers' model focuses on estimating secondary compaction based on three topographic surveys. Olivier (2003) introduces the notion or compaction rate or speed (determined based on the compaction derivative):

$$\rho(t) = \frac{1}{H}\cdot\frac{\mathrm{d}s}{\mathrm{d}t} = \frac{C_{ae}}{t\ln 10} \cong 0.434\frac{C_{ce}}{t};\quad C_{ae} = \ln 10\frac{t_{x_2} - t_{x_1}}{1/\rho_1 - 1/\rho_2};$$

$$\frac{\Delta s_0^1}{H} = \rho_1 \Delta t_1 \text{ and } \rho_1 = \frac{C_{ae}}{t_{x_1}\ln 10} \rightarrow t_{x_1} = \frac{C_{ae}}{\rho_1 \ln 10};$$

$$\frac{\Delta s_1^2}{H} = \rho_2 \Delta t_2 \text{ and } \rho_2 = \frac{C_{ae}}{t_{x_2}\ln 10} \rightarrow t_{x_2} = \frac{C_{ae}}{\rho_2 \ln 10}.$$

Supposing that the $t_{x_2} - t_{x_1}$ value is known, a new expression of C_{ae} may be determined, which only depends on this decrease and on the compaction rate. The latter may be calculated relying on a compaction chart, shown in Fig. 2. However, the height of the pile of waste should be approximated.

The t_{x_1} and t_{x_2} values may be determined relying on the C_{ae} value. The work completion date may be ultimately estimated, even when it is considered unknown.

The remark related to the adjustment of the model for a site with unknown history is also valid in this case.

Coumoulos & Koryalos (1997) also suggested a model which uses the notion of compaction rate (Fig. 3). This method is based on the remark according to which rapidly filled tailings have a compaction rate superior to that of tailings built over a longer period of time.

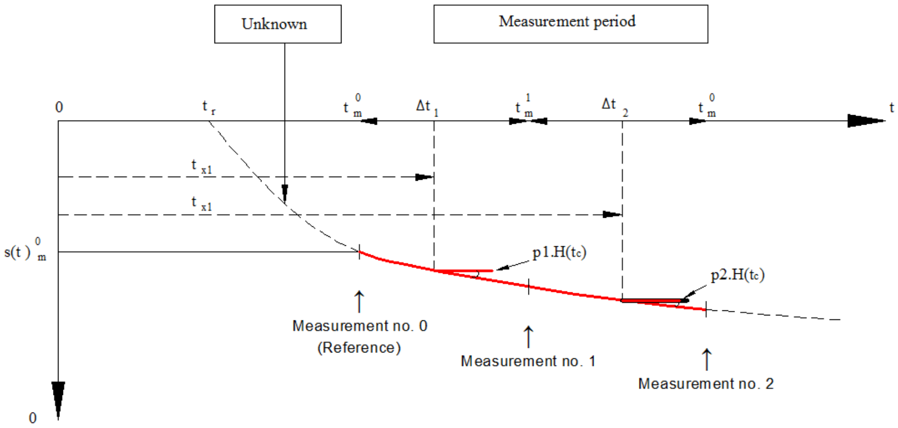


Fig. 2 – Notations used for the mitigation equation.

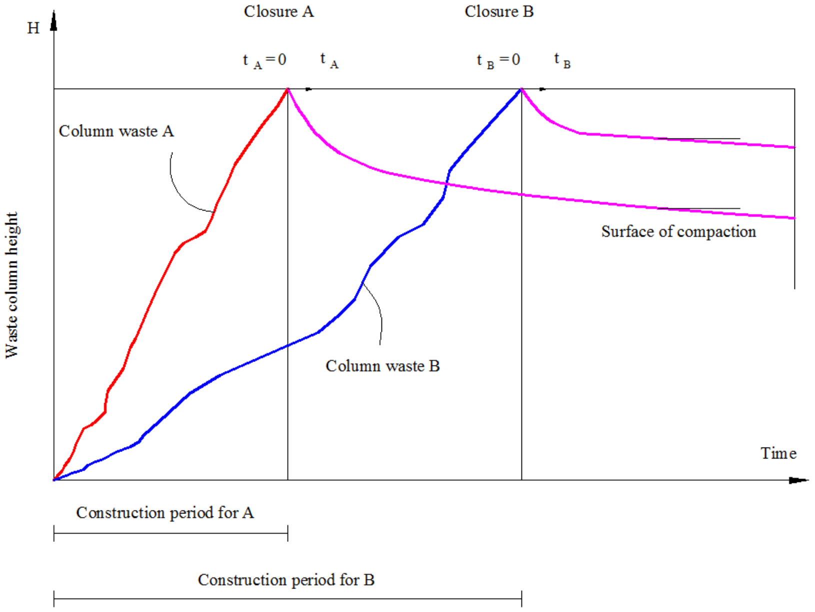


Fig. 3 – The compaction curves of the two piles have different construction periods.

Based on Sowers' secondary compaction equation, the different construction periods define the vertical deformation rate caused by long-term compression:

$$\rho = \frac{0.434C_{ae}}{t}.$$

When replacing the vertical deformation rate by y, a mitigation equation is obtained.

The use of the compaction rate allows the grouping of different data and their easier comparison.

According to the authors, when the compaction measurements and the tailing closing down date are known, C_{ae} may be determined starting on the compaction curve. When this information is not available, the authors suggest an information determination method. They also define a chart (Fig. 4) with C_{ae} values determined based on measurements performed on various sites.

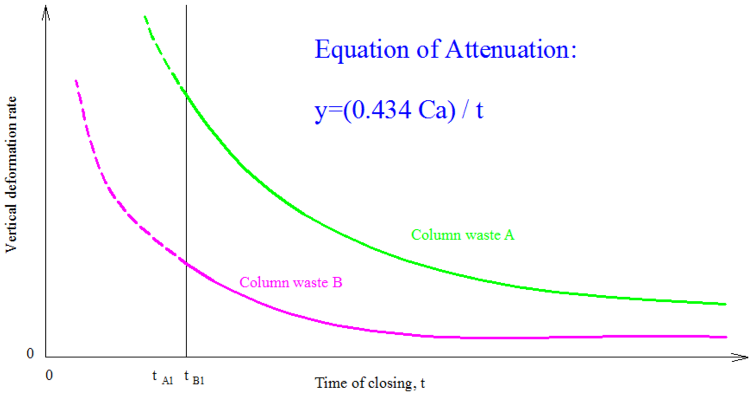


Fig. 4 – Vertical deformation rata mitigation curves for piles A and B.

Coumoulos & Koryalos (1999) also suggest that an uncertainty parameter be used, which represents the model parameter approximation deviation, based on the data available:

$$\text{SEM} = \frac{\rho}{\sqrt{n}}.$$

According to the authors, a simple compaction analysis, followed by an uncertainty analysis may be a valuable instrument for the development of the model.

E.3. Model suggested by Sharma & De (2007)

The authors studied secondary compaction by relying on Sowers' method and concluded that it may be divided into two categories, depending on the type of load applied.

The first category represents the compaction caused by the actual weight of the waste. The expression of this compaction is achieved in the long run and it is expressed in the following manner:

$$S_s = S_{(\mathrm{SW})} = C_{a(\mathrm{SW})} H_p \log \frac{t_2}{t_1 - t_0}.$$

The second category takes into consideration the compaction caused by exterior loads. It is defined in the following manner:

$$S_s = S_{(\mathrm{EL})} = C_{a(\mathrm{EL})} H_p \log \frac{t_3}{t_1 - t_0}.$$

The authors draw the readers' attention to the fact that exterior loads are often applied over a longer period of time after the tailing has been closed down. Considering that compaction due to the weight of the waste is minimal during this period, the authors do not find it necessary to combine the compaction calculations due to the weight of the waste with the calculations regarding compaction due to exterior loads.

Sharma & De (2007) suggest different ranges of values of these secondary compression coefficients, namely:

$$0.10 < C_{a(\mathrm{SW})} < 0.40;\ 0.02 < C_{a(\mathrm{EL})} < 0.07.$$

Nonetheless, the authors draw our attention on the fact that they vary depending on the environmental conditions of the site and on the composition of the waste.

This method does not seem reliable since it does not take into consideration the stress of the loads applied for compaction calculation. According to the method, two distinct loads could generate the same compaction.

E.4. Model suggested by Van Meerten (1997) quoted by Olivier (2003)

This model derives from Haan's model (1994) and it describes a more general method than the one developed by Van Meerten *et al* quoted by Olivier (2003). The model described in this section is more evolved than the basic model suggested by the same authors.

This mathematical model used to estimate compaction is valid for a period of 50 years (approximately a third of the compactions occur during the first five years).

Based on onsite measurements, the authors suggest a power function defined in the following manner:

$$\varepsilon = 1 - \frac{H_{f\,\mathrm{in}}}{h_i^z} - c \ln\left(\frac{t - t_z}{t_z - t_0}\right).$$

This model allows the consideration of the history of the landfill and the variation of the height of the different layers. It allows a 50% improvement of the reliability of the model as compared to the basic model.

Based on these findings, the authors note a compaction decrease, which is obviously caused by biodegradation variation.

The authors suggest the application of the model after its checking and after onsite measurements, designed to allow us to understand what is really happening on the field.

This model seems too simplified to accurately render reality.

2.2. Janbu's Method (1989)

A. Assumptions

1° The mechanic behavior of peat and soft clays resembles the behavior of waste.

2° Post-closure landfill compaction comes down to the effects of creep.

B. Model

Starting from experimental studies made on various types of soils, Janbu and others set up a method to determine compaction velocities. They introduced a coefficient called the creep resistance (r_s), whose values depend on the soil nature.

The creep potential is defined as follows:

$$S = H/r_s .$$

Integrating the creep rate, secondary compaction depending on the creep resistance coefficient may be expressed by the equation:

$$s = \frac{H}{r_s} \ln \frac{t - t_0}{t_1 - t_0}.$$

Olivier (2003) proposes an application of this model considering the various layers that make up the landfill anatomy.

He defines the creep potential of a basic layer as follows:

$$S = \Delta ht = \frac{h_0}{r_s}.$$

Integrating the creep rate, secondary compaction may be expressed in relation to the creep resistance:

$$S = \frac{h_0}{r_s} \ln \frac{t - t_0}{t_1 - t_0}.$$

Olivier defines the mean creep resistance as:

$$\overline{r_s} = \frac{H}{\sum \frac{h_i}{r_{si}}}.$$

Lastly, the total compaction of a waste column is expressed by starting from the mean creep rate of such column:

$$s = \frac{H}{\overline{r}_s} \ln 10 \log \frac{t - t_0}{t_1 - t}.$$

In analogy to Sowers' model, Olivier deducts an equation of creep resistance depending on the secondary compression coefficient.

$$\overline{r}_s = \frac{\ln 10}{C_{ae}}.$$

C. Parameters r_s, t_1

Gourc *et al.* (1998) proposes a range of values from 10 to 100 for r_s (in analogy to waste behavior and peat and soft clay behavior).

Olivier (2003) reduces this range to values from 45 to 100. They correspond to values of C_{ae} comprised from 0.02 to 0.05. These values of C_{ae} are closer to the ones mentioned in literature than the ones obtained for the range from 10 to 100.

D. Considerations

Starting from these observations, Vanderkelen (2000) demonstrated that the ranges of values of r_s (10 to 100) are an accurate representation of reality. This range is nevertheless too vast and, considering the properties of a landfill, accurate values are particularly complex to identify.

Furthermore, the assumption that post-closure compaction is plain creep action is not real and is just an over-simplified perspective.

2.3. Gibson and Lo's Model (1961)

A. Assumption

1° Analogy between waste behavior and organic soil behavior (significant hole volume, high content of biodegradable organic matter, fast primary compaction and slower secondary compression of higher intensity) (Vanderkelen, 2000).

2° Model based on empirical observations.

3° Actual resistance $\sigma'(t)$ increases in time.

4° Rheological model (resistance of deformation) assesses the mechanical behavior of materials considered continuous and homogenous (Reddy, 2006).

B. Model

In their model, Gibson *et al.* (1957) proposed the replacement of the soil skeleton with a compressibility spring *a* placed in series with a Kelvin made up of a compressibility spring *b* connected in parallel with a dashpot λ/b.

The actual compression resistance $\sigma'(t)$ increases gradually in time when applied to a soil element.

The first spring *a* compresses instantaneously, while Kelvin compaction lags due to the dashpot. Compression *a* rises as actual resistance rises until its completion. This period is the primary consolidation phase.

During the gradual increase of actual resistance (Fig. 5), the dashpot starts compressing. The initial load taken by λ will be later transferred progressively to *b* till the total release λ. This effect is secondary consolidation.

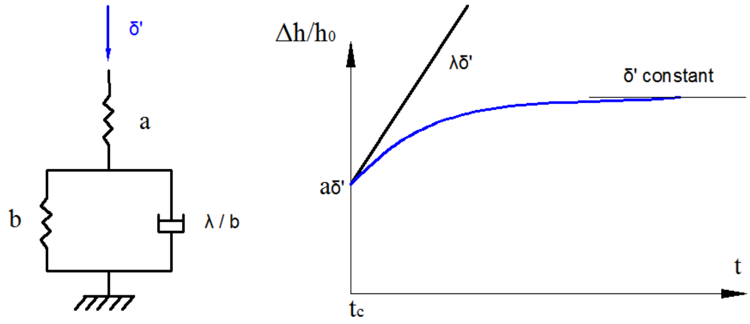


Fig. 5 – Representation of Gibsol and Lo's model.

Verbrugge (2000) provides a formula for actual resistance in relation to σ_b and σ_λ:

$$\sigma(t) = \sigma_b + \sigma_\lambda = \frac{f}{b} + \frac{1}{\lambda}\cdot\frac{\mathrm{d}f}{\mathrm{d}t}.$$

In this equation, $\sigma'(t)$ and f depend on depth. Knowing the condition $f(0) = 0$, an equation of total compaction as a time function can be determined:

$$S(t) = a\sigma'(t) + \int\left(\sigma'(\tau)\mathrm{e}^{-\frac{\lambda}{b}(t-\tau)}\right)\mathrm{d}t.$$

We get two expressions that define short-term and long-term compaction. To study waste compaction, long-term compaction will be used exclusively:

$$s(t) = \sigma' H\left[a + b\left(1 - \mathrm{e}^{-\frac{\lambda}{b}t'}\right)\right].$$

Gibson and Lo propose a law to determine long-term compaction in relation to infinite compaction:

$$S(t) = S_\infty \sigma' H \mathrm{e}^{-\frac{\lambda t'}{b}}.$$

where : $S_\infty = \sigma' H(a + b)$.

C. Parameters a, b, λ, s_∞

To determine the value of parameter b, Verbrugge (2000) proposes a diagram $\log\dfrac{s_\infty - s(t)}{\sigma' H}$ as a function of t'. The linear slope (t ») is $0.434\dfrac{\lambda}{b}$ and the intersection between it and the vertical axis is log$b$.

Goure (1998) proposes the following values for various parameters:

$$a = 9.3 \times 10^{-5}\,\text{KPa}^{-1};\ b = 1.3 \times 10^{-3}\,\text{KPa}^{-1};\ \lambda/b = 1.7 \times 10^{-3}\,\text{days}^{-1}.$$

According to Olivier (2003), the parameter was easily obtained by laboratory tests.

Park and others (2002) proposed a method to define three parameters (a, b, λ) starting from the equation of waste deformation derivative as a function of time:

$$\frac{\mathrm{d}s(t)}{\mathrm{d}t} = \sigma\lambda \mathrm{e}^{-\frac{\lambda}{b}t}.$$

The value $\mathrm{d}\xi/\mathrm{d}t$ should be tracked on a semi-logarithmic scale, and b and λ may be determined by geometric resolution:

a) the original ordinate is $\sigma'\lambda$;

b) the curve slope is $-\dfrac{\lambda/b}{\ln 10}$.

Starting from the equation below, the parameter was determined as:

$$a = \frac{s(t_1)}{\sigma} - b\left(1 - \mathrm{e}^{-\frac{\lambda}{b}t_1}\right).$$

Reddy (2006) underlines that parameters depend largely on applied resistances and that consequently prudence should be employed in generalizing them and when they are applied to other sites.

D. Considerations

Literature reveals several conclusions of authors who tested this method based on their applications and observations. The general result is that forecasts are not always true.

According to Edil *et al.* (1990), achieved results are often less satisfactory than the law of creep power (Olivier, 2003) (because of uncertainties in terms of waste saturation degrees and compression power intensity). Wall & Zeiss (1995) show that this model does not forecast compactions correctly.

According to some authors, this method represents incorrectly the real physical evolution of the landfill, as real secondary compression is generated mainly by biodegradation. Moreover, Reddy (2006) and El-Fadel *et al.* (1999) insist that the model is limited, as its application quite soon leads to constant compaction.

Eventually, various observations can be made on the parameters needed to apply the model. According to Guasconi (1995), the range of possible values for such parameters is quite vast and this is why they are so difficult to choose from. Moreover, the infinite compaction coefficient is needed to apply the method, as it is actually the value searched for.

E. Applications and adaptations

E.1. Edil *et al.* (1990)

They proposed an adaptation of Gibson and Lo's model by determining, based on observations, some intervals for parameters a and b depending on applied tension and λ/b depending on the mean deformation rate.

E.2. Bleiker *et al.* (1995) quoted by Olivier (2003)

These authors proposed an approach similar to that of Gibson and Lo, defining compaction in the following manner:

$$s(t) = \sigma\left[a + b\left(1 - \mathrm{e}^{-\frac{\lambda}{b}t}\right)\right].$$

Values a and b depend on the applied tension.

E.3. El-Fadel *et at.* (2000)

Authors rely on the rheological model presented by Zimmerman (1972) quoted by Olivier (2003) which is based on the micropore concept. This model is defined starting from two partial differential equations (one of them being non-linear) that include the effects of deformation, biochemical and chemical decomposition, variations of the saturation degree and creep variations.

El-Fadel *et al.* propose this method of long-term compression modeling by a Kelvin combined with a spring and a dashpot in series. The proposed equation is quite complex (involves more than 10 parameters) and consequently its application is unlikely.

2.4. Edil and Others' Model: Power Law (1990)

A. Assumptions

1° Experimental measurement-based model.

2° Rheological model establishing the relationship between deformation and tensions.

3° Secondary compaction is caused by the effects of creep.

B. Model

Creep power law (under constant tension) shows compaction in relation to time as:

$$s = H\sigma m\left(\frac{t_3}{t_r}\right)^n .$$

In literature there is another equation of this model based on compaction rate:

$$\rho = \frac{\mathrm{d}s}{\mathrm{d}t} - \frac{p}{t^q}.$$

By integrating the compaction rate, the following equation of the compaction rate is obtained:

$$s = \frac{p}{1-q} t^{1-q}.$$

C. Parameters *n*, *m*, *p*, *q*

Edil and others propose values for coefficients determined further to observations about the behavior of certain sites:

$m = 2.5 \times 10^{-5}$ kPa^{-1}; $n = 0.55$ in average;
$m = 3.4 \times 10^{-5}$ kPa^{-1}; $n = 0.37$ for old compacted wastes;
$m = 2.0 \times 10^{-5}$ kPa^{-1}; $n = 1.5$ for recent wastes.

Coefficients p and q are determined by empirical means and depend on the waste properties, landfill characteristics and environment conditions.

D. Considerations

The conclusions of various authors on the application of this method show clearly that this model does not forecast correctly compactions and has certain limitations.

Hence, Olivier (2003) says that this function tends to be divergent, involving a net overestimation of compaction. Verbrugge (2000) says also that the validity of this model should be considered with caution when n > 1.

Ling *et al.* (1998) outline two limitations of the model. Should q be equal to 1, this will forecast infinite compaction, and should p be positive and q higher than 1, the method will supply negative compaction (which is physically impossible). They observe (like in Yen and Scanlon's model) that over long periods of time, the model will forecast infinite compaction.

Moreover, Guasconi (1995) demonstrates that the model is based on Gibson and Lo's model and consequently is subject to the same limitations (it shows incorrectly the physical reality, as most secondary compaction is generated by biodegradation, not just the effects of creep). As Park *et al.* (2002) noticed, this model is not forecasting correctly waste compaction because it does not consider compression acceleration by biodegradation.

Reddy (2006) and El-Fadel *et al.* (1999) notice another inconvenient of the model, as does not enable the determination of the time period of compaction stabilization.

Nevertheless, Qian *et al.* (2002) noticed that this model forecasts compaction better than the Yen and Scanlon's model.

3. Conclusions

The mechanisms responsible for compaction in landfills are more numerous and much more complex than the mechanisms affecting soils. The structure of any refuse collection, which is very heterogeneous, is fundamentally altered over time due to the amount of biodegradable organic matter and to the impressive volumes of empty spaces present in the landfill.

The methods described in our paper enable us to conclude that the follow-up of landfills through a multitude of parameters is very important.

Landfill compaction and compaction rate depend on many parameters that may interact:

a) type of waste (especially the percentage of organic matter);
b) void ratio;
c) volumetric weight and density;
d) height of the refuse collection in the landfill;
e) compaction method (compaction energy, compaction degree, etc.);
f) filling rate;
g) conditions influencing biodegradable organic matter decomposition (temperature, atmospheric conditions, water concentration, leachate and biogas production, etc.).

The determination of all these parameters, their relative importance and evolutionary nature are the source of the main waste compaction estimation and modeling difficulties.

Analogies are possible based on the soil mechanics principles, in order to assess landfill compaction, since, despite the fact that the processes involved and the parameters that should be considered are much more numerous, the evolution laws ultimately have certain similarities.

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STUDIU PRIVIND METODELE DE DETERMINARE A STABILITĂŢII DEPOZITELOR DE DEŞEURI APLICABILE ÎN CONDIŢII SPECIALE

(Rezumat)

Analiza problematicii tasării unui depozit de deşeuri stârneşte numeroase reacţii de aproximativ treizeci de ani. Astfel, nu este deloc surprinzător să descoperim în literatură un număr impresionant de legi şi de aplicări care îşi propun să modeleze tasarea deşeurilor în loc să controleze acest fenomen.

Obiectivul prezentei lucrari constă în prezentarea unei sinteze exhaustive a diferitelor legi de modelare a tasării deşeurilor, absolute şi diferenţiale, definite în literatură, şi în propunerea unei clasificări a acestor modele în diferite categorii. Acestea au fost stabilite plecând de la ipoteze şi principii pe care se bazează autorii acestora pentru elaborarea propriilor metode.

Legile prezentate în literatură sunt prezentate de diverşi autori într-o manieră proprie.

Pentru a facilita comparaţia acestora cu respectarea unor numeroase criterii, este important de prezentat rezultatul cercetărilor în baza unui tip de diagramă. Acesta se structurează în patru părţi (ipoteze, model, parametri şi apreciere) şi permite astfel o scoatere mai bună în evidenţă a avantajelor şi dezavantajelor fiecărui model.

Ecuaţiile diferite prezentate în aceasta lucrare au fost modificate în vederea uniformizării notării.