Building a subsidence prediction module and applying for Nam Deo Nai waste dump

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Abstract

Landslide and subsidence in waste dump is a major problem which most mining industry countries is facing, Viet Nam is not an exception. To reduce the effects of disasters such as subsidence, there have had many developed subsidence prediction methods. In this paper, prediction function of Knothe was presented. Based on Knothe function, the authors built a subsidence prediction module and applied it for Nam Deo Nai waste dump, Quang Ninh, Viet Nam. The predicted values from this module was compared to the actually measured data, the smallest difference of subsidence is -0.003 m, equivalent to 5.3%, the largest difference is 0.011 m, equivalent to 4.3%. The small disparity between the largest and smallest difference shows the result has a high convergence. As the final result, it is found that the developed module is powerful and effective tool for waste rock dumps subsidence prediction.

Keywords: WDSprediction, Waste rock dump, Subsidence prediction, Landslide, Nam Deo Nai.

1. Introduction

Many waste rock dumps can be considered as a potential source of environmental problems, such as subsidence, erosion and landslide, which lead to significantly negative impacts on surrounding areas where have many civil works as house, school, etc (Fig. 1a). There have been many serious incidences due to landslide at waste dumps of Vietnam National Coal – Mineral Industries Holding Corporation Limited (Vinacomin). For example, ten houses were buried due to the landslide occurring at the rock waste dump of Phan Me coal mine (Thai Nguyen Iron and Steel Joint stock Corporation) in early morning 15/4/2013 (Fig. 1b) (Vnexpress.net, 2013). Vinacomin has taken many solutions in order to increase the stability of waste dumps, such as dumping by benches, dumping by surface, building the system of walls at the food of waste dump and planting trees, etc. However, it is necessary that waste dumps are monitored frequently and then the warnings of environmental hazards are informed earlier. Therefore, many monitoring works have been built in large waste dumps by mining companies owned by Vinacomin.

Fig. 1a. Civil works at waste dump's food

Fig. 1b. Dump site slide at Phan Me mine in 2013

2. Subsidence prediction algorithm

Subsidence in waste dumps is very strong at the beginning stage and this process decreases after a period of time. The Knothe time function can be used to describe the process of subsidence at waste dumps. Subsidence value of point is defined by the equation (1). The form of subsidence over time of point and its movement speed as Fig. 2 (Khanh, 1997).

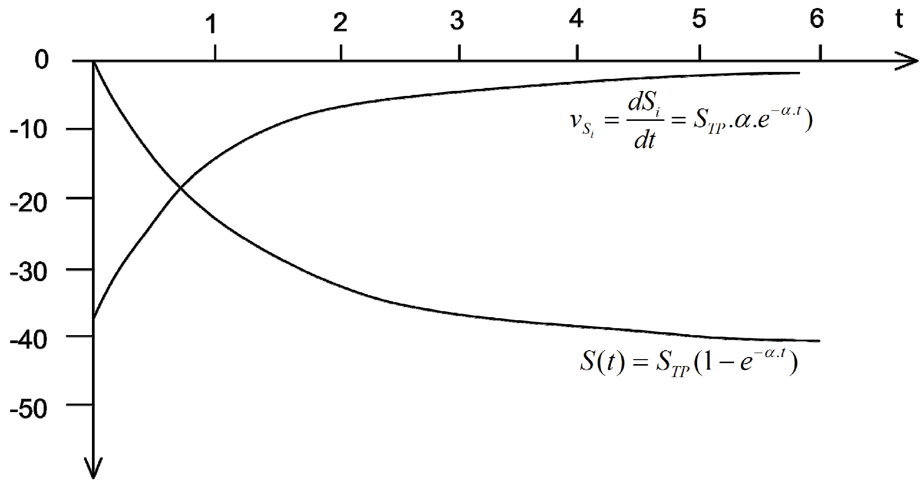

Fig. 2. Subsidence and subsidence speed curves

$$S(t) = S_{TP}(1-e^{-\alpha.t}) \quad \text{(Khanh, 1997)} \tag{1}$$

Where,

S_{TP} - Total subsidence value;

α - Time parameter.

To determine the total subsidence value (S_{TP}), it is necessary to measure multiple periods until subsidence process ending. However, if the number of monitoring periods is greater than 2, the values S_{TP} and α can be identified by equation (1). The approximate value of S_{TP} and α are identified by least mean principle [VV] = min.

Taylor expansion for equation (1) then:

$$S_{t_i} = \left(S_{t_i}\right)_0 + \left(\frac{\delta S_{t_i}}{\delta\alpha}\right)\Delta\alpha + \left(\frac{\delta S_{t_i}}{\delta_{TP}}\right)\Delta S$$

Where,

$\Delta\alpha = \alpha - \alpha_0$;

$\Delta S = S_{TP} - \left(S_{t_i}\right)_0$;

$\Delta S_{t_i} = \left(S_{TP}\right)_0\left(1-e^{\alpha_0.t}\right)$.

Where,

α_0 is the approximate value of α;

$\left(S_{TP}\right)_0$ is the approximate value of S_{TP}.

Sign $\left(\frac{\delta S_{t_i}}{\delta S_{TP}}\right) = (S_{TP})_0.t_i e^{-\alpha_0 t_i} = a_i$ and $\left(\frac{\delta S_{t_i}}{\delta\alpha}\right) = (1-e^{-\alpha_0 t_i}) = b_i$ then the correction equation by period i can be expressed as below:

$$v_i = a_i\Delta S + b_i\Delta\alpha + l_i \tag{2}$$

Where,

$v_i = S_{t_i} - (S_{t_i})_{mea}$;

$l_i = (S_{t_i})_0 - (S_{t_i})_{mea}$.

From the system of correction (4), the system of normal equations can be written:

$$[\mathrm{a}_i\mathrm{a}_i]\Delta\mathrm{S}+[a_ib_i]\Delta\alpha+[a_il\ ]=0$$
$$[\mathrm{a}_i\mathrm{b}_i]\Delta\mathrm{S}+[b_ib_i]\Delta\alpha+[b_il_i]=0 \tag{3}$$

Solving the system of normal equations obtained ΔS and $\Delta\alpha$, the best probability value of S_{TP} and α are calculated as below:

$$S_{TP}=\left(S_{TP}\right)_0+\Delta S$$
$$\alpha=\alpha_0+\Delta S \tag{4}$$

Subsidence speed of point is given by equation (5):

$$v_{S_i}=\frac{dS_i}{dt}=S_{TP}.\alpha.e^{-\alpha.t}) \tag{5}$$

3. Building a waste dump subsidence prediction module

There are many quite completed subsidence prediction software in the world, investment cost to purchase these software is too high so it can not bring economic efficiency for Vinacomin. In this circumstance, the WDSprediction module was built. WDSprediction has met the basic requirements such as easy to use, ensure the accuracy, allows importing and updating data from Notepad and Excel, etc. This software allows automated processing of monitoring data and forecasting the subsidence of waste dump. The result can store in the form of text or graphical format as DXF and DWG standard.

The module was written in Visual C++ language which is object-oriented programming for application development in the Windows environment. Visual C ++ is inherited the advantages such as flexibility, compatible with hardware devices (Mcauley, 2000). The WDSprediction module runs in the Windows environment and inherited much advantage from the standard library platform, data is exchanged easily with other software such as Excel, AutoCAD, etc. It is integrated in the AutoCAD software menu and illustrated in Fig. 3. The main features of the module are data monitoring processing and waste dump subsidence prediction.

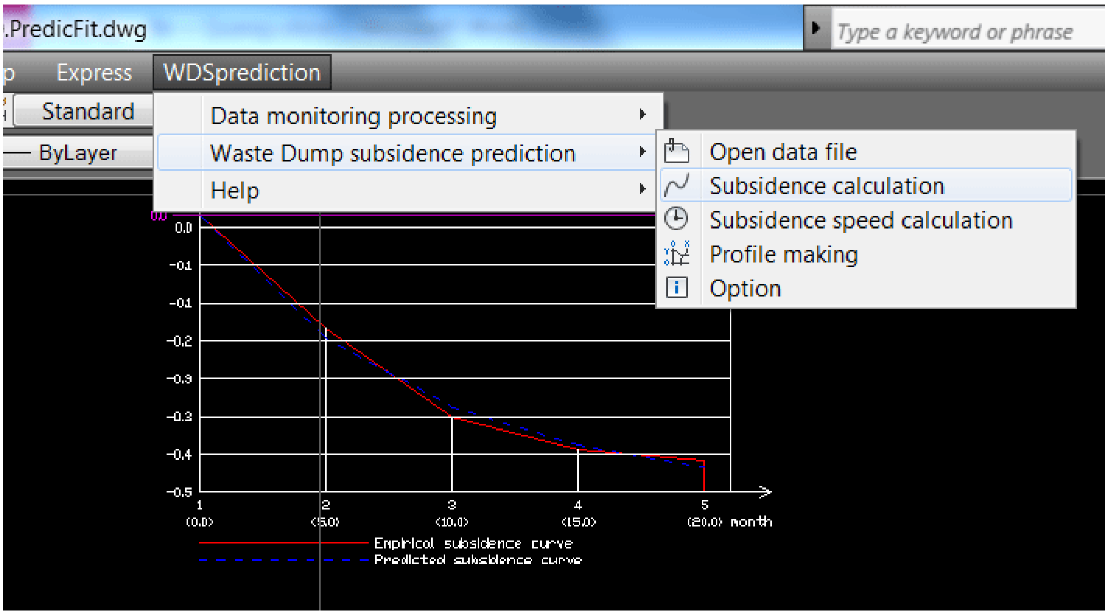

Fig. 3. Menu of WDSprediction module

4. The use of "WDSprediction" for Nam Deo Nai waste dump

There are 6 monitoring routes at Nam Deo Nai waste dump, 2 routes include 4 points and 4 routes include 3 points. These routes are located on different working benches (220m, 250m, 280 m) to determine displacement in the different conditions. The monitoring points as shown in fig. 4 (Dung, 2014).

- Bench 280m has 1 route which includes 3 monitoring points named 18, 26, 13.

- Bench 250m has 1 route which includes 4 monitoring points named B1, B2, C1, C2.
- Bench 220m has 4 routes which include 10 monitoring points named A1, A2, 1, 3, 5, 6, 7, 12, 14, 15.

To evaluate the accuracy of forecasting methods and the applicability of WDSprediction module, the authors used leveling data of the first 4 periods of the points A1, A2, 7 and 12 to build forecasting models. From the prediction models, forecasting subsidence for the subsequent period then making a comparison of predicted results and the measured value in the 5th period (20 month). Leveling measurement subsidence of 4 selected points is shown in table 1.

Table 1. The subsidence measurement data

Unit: meter

Name of point	Measurement subsidence				
	0 month	5 month	10 month	15 month	20 month
A1	0	-0.19	-0.339	-0.395	-0.414
A2	0	-0.166	-0.203	-0.230	-0.254
7	0	-0.113	-0.189	-0.241	-0.298
12	0	-0.187	-0.251	-0.280	-0.302

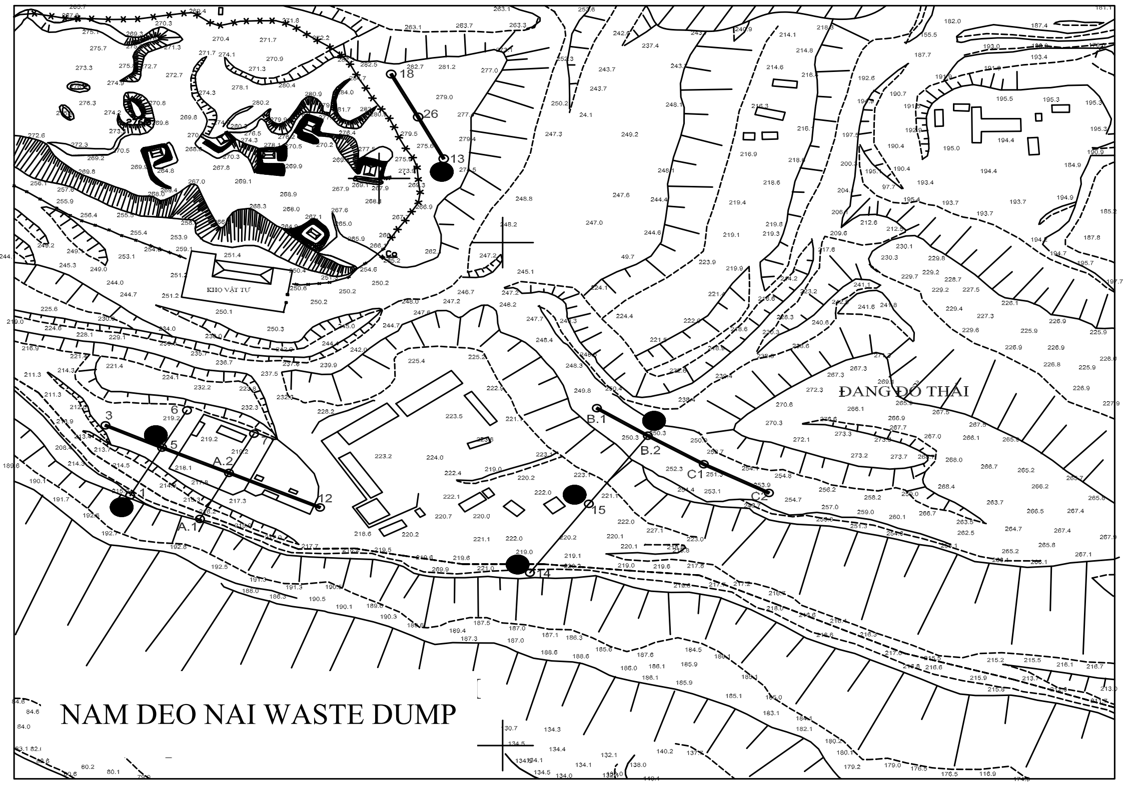

Fig. 4. The monitoring points at Nam Deo Nai waste dump (Dung, 2014)

The values of S_{TP} and α are determined by given equations from (2) to (5). Using these parameters S_{TP} and α to predict the subsidence of 4 above points at 20th month. The value of subsidence prediction is as shown in table 2.

Table 2. The difference between predicted value and measured subsidence

Unit: meter

Name of point	time (month)	Measurement	Prediction	Difference
A1	20	-0.414	-0.424	0.010
A2	20	-0.254	-0.243	0.011

7	20	-0.298	-0.295	-0.003
12	20	-0.302	-0.296	-0.006

From the results in table 2, compare the predicted value to the measured data, the smallest difference is -0.003 m at point 7, equivalent to 5.3%, the largest difference is 0.011 m at point A2, equivalent to 4.3%. The measured subsidence of points and its corresponding predicted values by WDSprediction are shown in Fig. 5.

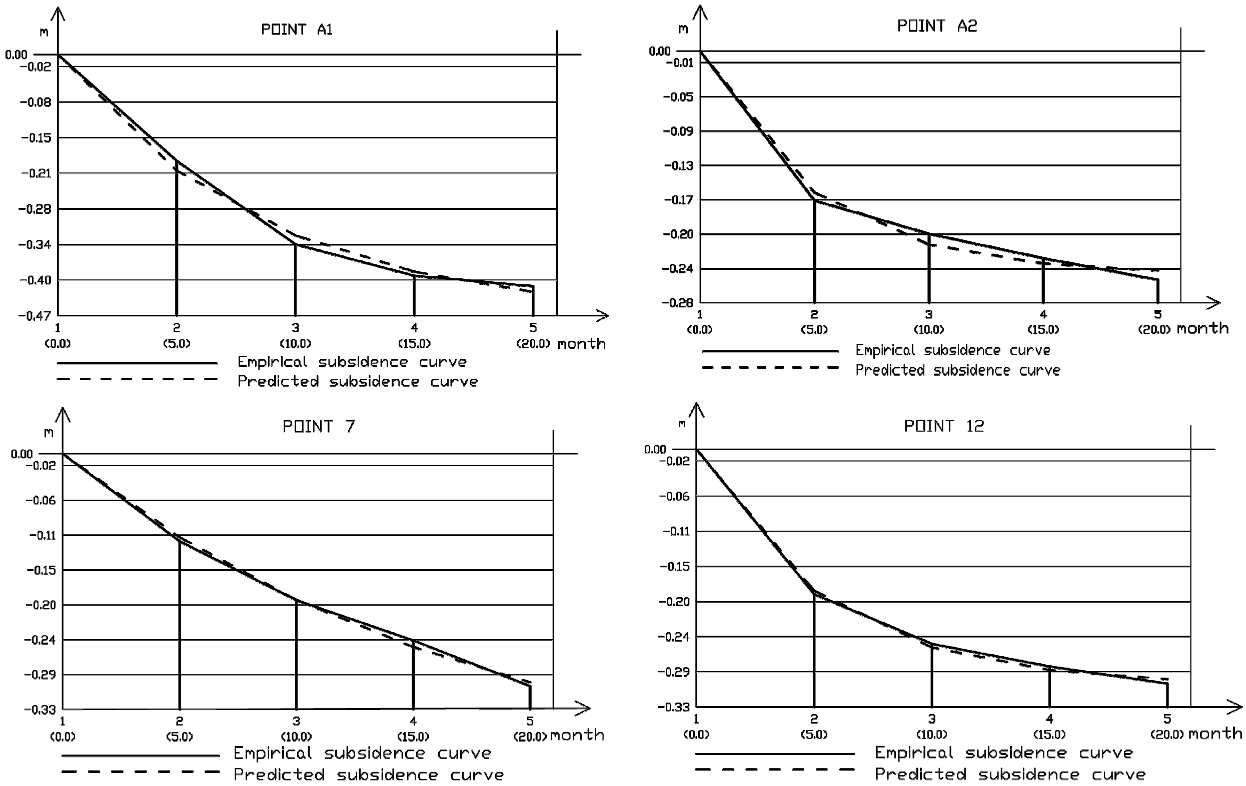

Fig. 5. The curves of point subsidence and its predicted value

4. Conclusions

The paper mentioned to the using of Knothe time function to predict waste dump surface subsidence. From the algorithm, WDSprediction module has been built. This is an AutoCAD integrated module for monitoring processing and dumpsite subsidence prediction. Applying WDSprediction allows us to calculate the movement rapidly and to predict the subsidence accurately.

The accuracy of forecasted results and display capacity as well as data exchange show that WDSprediction was built based on corrected algorithms and a suitable programming language. It is a powerful tool that allows calculation, storage and display information about the process of moving waste dump. WDSprediction can be applied in teaching opencast mining and mine surveying field.

Applying the developed module for waste rock dumps subsidence prediction at the Nam Deo Nai waste dump, Quang Ninh, Viet Nam, some below results were drawn:

- The smallest difference of subsidence is -0.003 m, equivalent to 5.3%;
- The largest difference is 0.011 m, equivalent to 4.3%;
- The small deviation between the largest and smallest difference shows the result has a high convergence.

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