J. of Hydrau., Coast. and Environ. Eng. No. 521/Ⅱ-32, 249-255, 1995. 8

# ESTIMATION OF OPTIMUM OPERATING PARAMETERS OF UASB REACTOR TREATING FLAX RETTING WASTEWATER BY KINETIC MODEL

Jun LIU[1], Masao UKITA[2], Hiroshi NAKANISHI[3], Tsuyoshi IMAI[4],
and Masayuki FUKAGAWA[5]

[1]Member of JSCE, M. Eng., Graduate Student, Dept. of Civil Eng., Yamaguchi University ( Ube, Yamaguchi 755, Japan )
[2,3]Member of JSCE, Dr. Eng., Professor, Dept. of Civil Eng., Yamaguchi University (Ube, Yamaguchi 755, Japan )
[4]Member of JSCE, M. Eng., Assistant, Dept. of Civil Eng., Yamaguchi University (Ube, Yamaguchi 755, Japan )
[5]Member of JSCE, Dr. Eng., Professor, Dept. of Civil Eng., Ube Technical College (Ube, Yamaguchi 755, Japan )

A laboratory study was used to develop a simplified kinetic model, to evaluate the kinetic parameters, and to provide rational design parameters for a pilot plant treating flax retting wastewater by means of the simulation of optimal operation of the UASB reactor. The results indicated that the developed model can be used predicatively for assessing plant performance and when the concentration of the influent is at the range of 5.5～7.3 gCOD/l, the concentration of the hard-biodegradable materials is 0.46 gCOD/l.

***Key Words:*** *flax retting wastewater, UASB reactor, kinetic model, optimum operating parameters*

## 1. INTRODUCTION

Anaerobic digestion is among the oldest biological wastewater treatment processes, having first been used more than one hundred years ago[1)]. Recognition of the advantages of anaerobic processes, over those of aerobic processes, has led to the development of various anaerobic processes. The upflow anaerobic sludge blanket (UASB) process, developed by Lettinga and his coworkers in 1970's, has received widespread acceptance and been successfully used to treat a variety of industrial wastes, particularly those produced by food processing industries[2),3)].Flax retting wastewater stems from the flax preprocessing of flax retting factory in which the flax is retted in the water with mesophilic temperature about 3 or 4 days in order to separate the fiber from the woody material by the natural degradation. Volatile fatty acids are produced, at same time the lignin and other hard-biodegradable materials, were also diffused in water during the retting process. Pipyn and Verstraete investigated the treatment of this kind of wastewater using UASB system in which around 87% COD reduction was achieved[4)].

Despite the effectiveness and technological advances of the UASB process for treating flax retting wastewater, most of the UASB data existing in the literature do not include kinetic descriptions[4)] making it difficult to assess the effect of operating variables. In order to quantify the performance of an UASB system, it is necessary to develop relationships for the effect of operating variables, such as loading rate and hydraulic retention time, on substrate utilization, biomass and product formation. However, in order to construct an integral reactor model of the UASB reactor, besides a model describing the fluid flow pattern and the distribution or behavior of sludge, the kinetics of the conversion of organic wastes and the formation of methane and of bacterial waste products have to be known[5),6)]. On the other hand, anaerobic digestion of organic wastes is sequentially processed by different groups of bacteria and the product (s) of one group being the

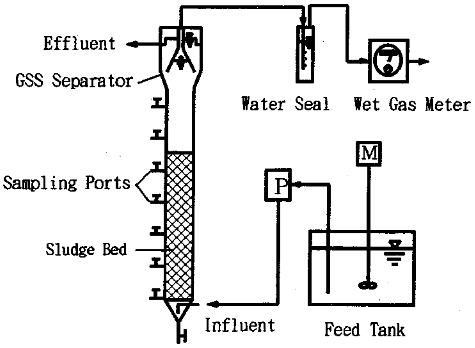


**Fig. 1** Schematic diagram of a lab-UASB reactor

**Table 1** Characteristics of Wastewater

| Characteristics | Value |
|---|---|
| $COD_{cr}$ | 5530~7290 mg/l |
| $BOD_5$ | 3220~5100 mg/l |
| TOC | 2280~4000 mg/l |
| VFA | 3350~4890 mg/l |
| Lignin | 245~356 mg/l |
| pH | 4.9~5.5 |
| Total N | 77~80 mg/l |
| Total P | 25~48 mg/l |
| SS | 55~110 mg/l |

substrate for another group7). Therefore, the kinetic models based on such a situation necessarily involve a number of kinetic equations and parameters making them very complex5)-6), 8). To some extent complexity does not mean accuracy and the empirical simplification is required for a simpler modeling based on COD. The objectives of this work are to develop a simplified kinetic model, to evaluate the kinetic parameters, and to provide a rational design parameters of this wastewater for a pilot plant by means of the simulation.

## 2. MATERIALS AND METHODS

### (1) Experimental apparatus

A schematic diagram of lab-scale UASB reactor used in this study is shown in **Fig. 1**. The reactor consisted of a cylindrical glass tube ( 10 cm i.d. × 170 cm height ) having an effective volume of 12 l, and seven sampling ports placed along the reactor height were used. The reactor was maintained at 35℃ in a temperature controlled room. Effluent was removed from the top of the reactor through a gas-liquid-solid separator. Gas was evolved from the reactor through a wet gas meter used to measure biogas production.

**Table 2** Operation and run variables

| Run | HRT (d) | pH Inf. | pH Eff. | Loading rate (gCOD/l/d) | COD removal (%) | X gVSS/l | $X_e$ gVSS/l | $CH_4$ (Nl/d) |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 5.3 | 7.5 | 4.4 | 92.0 | 15.1 | 0.08 | 16.2 |
| 2 | 1.0 | 5.2 | 7.4 | 6.7 | 91.0 | | 0.13 | 25.8 |
| 3 | 0.75 | 5.2 | 7.5 | 8.5 | 87.9 | | 0.17 | 34.3 |
| 4 | 0.67 | 5.3 | 7.4 | 10.0 | 85.0 | | 0.20 | 37.6 |
| 5 | 0.5 | 5.3 | 7.5 | 14 | 81.5 | | 0.23 | 51.5 |
| 6 | 0.4 | 5.4 | 7.5 | 17 | 75.7 | | 0.33 | 59.0 |

### (2) Wastewater characteristics

The characteristics of flax retting wastewater used in the experiment were summarized in **Table 1**.

### (3) Chemical analysis

pH was gotten by a glass-electrode pH meter. SS, VSS, lignin, COD, BOD, T-N and T-P were analyzed according to the Standard Methods9), and TOC was measured by SHIMADZU TOC-10B. Gas compositions and volatile fatty acids (VFA) were measured with a gas chromatography method.

### (4) Start-up and process operation

The inoculum was prepared as follows: 2 l anaerobic digested sludge (15.2 gVSS/l) from a municipal sewerage treatment plant and 1 l sludge from the sewer of flax retting factory were filled to the reactor and 2-4 $gNaHCO_3/l$ was added to the influent in order to keep pH between 6.8 and 7.3. The initial loading rate was 2.2 ($kgCOD/m^3/d$). The more than 80% COD and BOD removal were achieved after seven weeks. After a 7 week start-up period, lab-scale experiments over a eight month period were conducted to investigate the feasibility of the UASB process for flax retting wastewater treatment, and then six continuous flow runs were carried out over a eight week period to evaluate the kinetic parameters of the UASB reactor.

Since anaerobic bacteria have a small growth rate during this period the biomass content of the reactor was assumed constant and was measured in the end of experiment. The data obtained at steady state during this period are shown in **Table 2** ( each value is the average value ).

## 3. SUBSTRATE UTILIZATION MODEL

As a part of the development of an integral mathematical model describing the UASB reactor, the kinetics of the conversion of organic wastes is the most important. At present, complex models, consisting of multivariables are applicable only to research studies. It is difficult to apply these complex models to control and predict plant operation performance and to optimize plant design and scale-up the pilot study results. However, simplified models, involving only a few variables, are easier to develop and are need for industrial application.

In biological wastewater treatment, Monod model is widely applied for describing the relationship between reaction rate and substrate concentration in methane fermentation process. Monod-based models have unquestionable accuracy in predicting process failure and optimum[7]. Furthermore, first-order kinetic models, used in anaerobic digestion, are simplification of the Monod model[10]. According to the literature[11),12)], the UASB reactor has two distinct characteristics: the sludge bed and blanket can be described as a combination of a completely mixed region and well mixed region and the flow characteristics in the setting zone can be described as plug flow. However, taking account of the effect of rising gas bubbles from the sludge bed and blanket zone, it is reasonable to assume the UASB reactor to be completely mixed flow. The Monod model applied to the observed specific substrate utilization rate is usually written as:

$$U=\frac{U_{max}\times S}{K_s+S} \tag{1}$$

where, $U_{max}$ is the observed maximum specific rate of substrate utilization ( gCOD/gVSS/d ); $K_s$ is the half-velocity constant ( g/l ); S is substrate concentration ( g/l ). In consideration of existing of some hard-biodegradable materials ( such as lignin ), therefore, a modified Monod model was developed for the curve fitting of specific substrate conversion rate.

$$V=\frac{V_{max}\times(S_e-S_n)}{K_s+(S_e-S_n)} \tag{2}$$

where $S_n$ is COD concentration of hard-biodegradable materials, in theory, which is equaled by $S_e$ at V=0. By linear arranging equation (2), the following equation is given:

$$\frac{1}{V}=\frac{K_s}{V_{max}}\times\frac{1}{S_e-S_n}+\frac{1}{V_{max}} \tag{3}$$

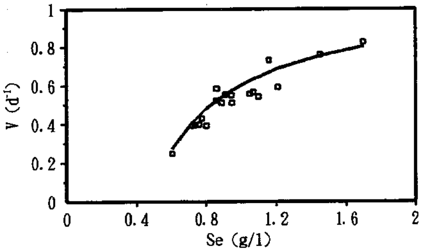


**Fig. 2** The relationship between the specific rate of substrate conversion and effluent COD.

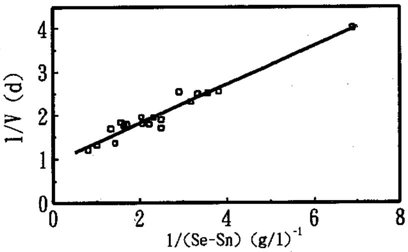


**Fig. 3** The plot of reciprocal number of the specific substrate conversion rate versus the reciprocal number of biodegradable effluent COD.

**Fig. 2** showed the relationship between the specific rate of substrate conversion and effluent COD concentration $S_e$ ( g/l ) in steady state. From the intersection of regression curve and X-axis $S_n$ can be ascertained. In this study $S_n$ was determined by using quasi-Newton's method which had the maximum correlation coefficient as object and the computing results released that $S_n$ was 0.46 g/l. Therefore, it can be inferred that under the similar conditions of the experiment, the highest COD removal of flax retting wastewater is:

$$\eta_{max}=\frac{(5.5\sim7.3)-0.46}{(5.5\sim7.3)}\times100\%=91.6\sim93.7\%$$

The graphical representation of equation (3) was shown in **Fig.3** by means of Lineweaver-Burk plot method. From **Fig.3** the maximum specific rate of substrate conversion, $V_{max}$, was 1.085 ( gCOD/gVSS/d ), and the half-velocity constant, $K_s$, was 0.433 ( g/l ). Regression results showed a good correlation ( $R^2$=0.944 ). Thus equation (2) can be written as:

$$V=\frac{1.085\times(S_e-0.46)}{0.433+(S_e-0.46)} \tag{4}$$

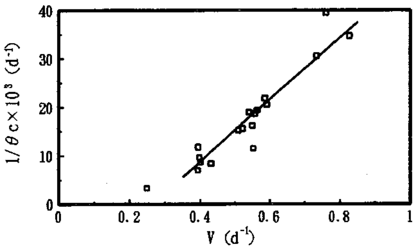


**Fig. 4** The relationship between $1/\theta_c$ and V

## 4. MICROORGANISM GROWTH MODEL

The microorganism growth basic equation can be generally written as:

$$\frac{1}{X}\frac{dX}{dt} = Y \times V - K_d \tag{5}$$

where $1/X \cdot dX/dt$ is microorganism net specific growth rate; X is concentration of biomass ( gVSS/l ); Y is yield coefficient ( gVSS/gCOD ); V is specific rate of substrate conversion; $K_d$ is decay coefficient ( $d^{-1}$ ).

Consider the biological mass balance

Rate of accumulation=Rate of flow in - Rate of flow out + Rate of appearance=$QX_o - QX_e + V_o \times dx / dt$

where $X_o$ is biomass of influent ( gVSS/l ); $X_e$ is biomass of effluent ( gVSS/l ); Q is the daily flow rate ( l/d ); $V_o$ is volume of the reactor operated in the steady state ( l ) and the biomass in influent was not dealt with the equation (5) can be written as:

$$\frac{QX_e}{V_oX} = Y \times V - K_d \tag{6}$$

Moreover, according to the concept of biological solids retention time ( SRT expressed in form of $\theta_c$ in later ).

$$\theta_c = \frac{V_oX}{QX_e} \tag{7}$$

Combining the equation (6) and (7) leads to the following expression:

$$\frac{1}{\theta_c} = Y \times V - K_d \tag{8}$$

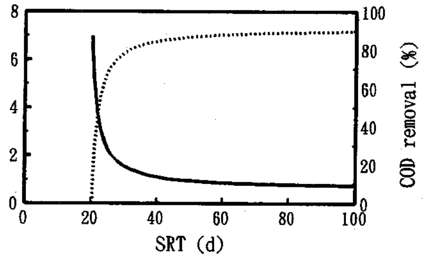


**Fig. 5** The relationship between solids retention time, effluent COD concentration and treatment removal.

**Fig. 4** showed the relationship between the microorganism net specific growth rate ( $1/\theta_c$ ) and the specific rate of substrate conversion ( V ) . From **Fig. 4**, the microbial yield coefficient, Y, was 0.0649 ( gVSS/gCOD ) and decay coefficient, $K_d$, was 0.0169 ( $d^{-1}$). Hence equation (8) can be rewritten as:

$$\frac{1}{\theta_c} = 0.0649 \times V - 0.0169 \tag{9}$$

Combining the equation (4) and (9) leads to the following expression:

$$\frac{1}{\theta_c} = 0.0649 \times \frac{1.085 \times (S_e - 0.46)}{0.433 + (S_e - 0.46)} \tag{10}$$

From equation (10) the relationships between average solids retention time (SRT), effluent COD concentration, and COD removal efficiency can be developed and results were shown in **Fig.5**, which indicated that the minimum SRT ( i.e. $S_e$=$S_o$ , where $S_o$ is influent COD ) was 21 d, and it is necessary to maintain a SRT of 45 d or more in order to achieve over 85% COD removal. Therefore, a three-phase separator with a good function was very important for an UASB reactor.

## 5. PARAMETER SENSITIVITY ANALYSIS

In order to determine the sensitivity of the response of the model to changes of the parameters of the model and to find out which parameter is the most important, an analysis of the sensitivity was carried out for the substrate utilization model. The relative variation of the effluent COD at HRT=1d, X=15.113gVSS/l and $S_o$=6.7 gCOD/l was defined as the sensitivity. The results of this analysis were shown in **Fig. 6**. It revealed that $V_{max}$ is the

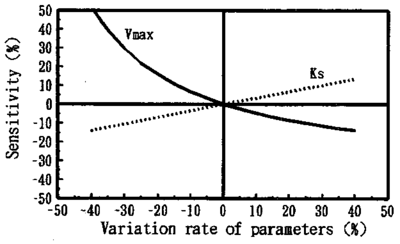


**Fig. 6** Sensitivity analysis of parameters in substrate utilization model.

parameter which influences the system most, so it has to be determined experimentally and most accurately. This is the same as the results of former investigators[13].

## 6. SIMULATION OF OPERATING PARAMETERS

Despite the widespread use of anaerobic treatment, optimum process performance is seldom achieved because of the high degree of experimentalism which prevails in design and operation. The knowledge of process kinetics can establish a rational basis for system analysis and design. So in this study we used the developed model to predict the effect of operating variables( e.g. HRT, $S_o$ and X ) on substrate removal, and to estimate the optimum operating parameters. Hence, rearranging the equation ( 4 ) the equation can be developed showing the relationship between $S_e$ and X, HRT as well as $S_o$.

$$\frac{1.085\times(S_e-0.46)}{0.433+(S_e-0.46)}=\frac{S_o-S_e}{X\bullet \mathrm{HRT}} \qquad (11)$$

Using this equation, $S_e$ was calculated for given values of X, HRT and $S_o$, which were changed within the practical range. Then the COD removal was obtained. **Fig. 7-a**, **7-b** and **7-c** are the relationships of HRT and COD removal when the sludge concentration ( X ) are 10, 15, 20 gVSS/l, and influent COD ( $S_o$ ) are 7.3 g/l ( maximum COD concentration of raw water ), 6.7 g/l ( average COD concentration of raw water ), 5.5 g/l ( minimum COD concentration of raw water ), respectively. These figures indicated that the influence of $S_o$ was small. **Fig. 8** summarized the effect of HRT on COD removal at different sludge concentration at $S_o$=6.7 g/l. Similarly, **Fig. 9** summarized the effect of sludge concentration on COD removal at different HRT at

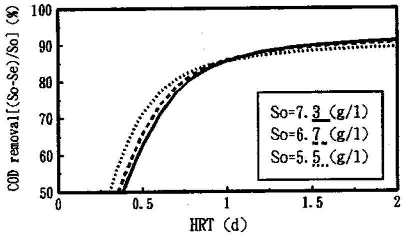


**Fig. 7-a** The effect of HRT on COD removal. (X=10 gVSS/l)

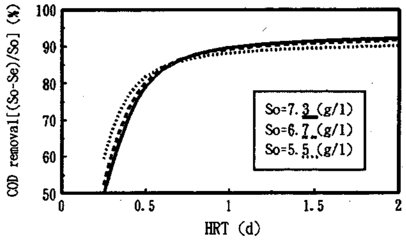


**Fig. 7-b** The effect of HRT on COD removal. (X=15 gVSS/l)

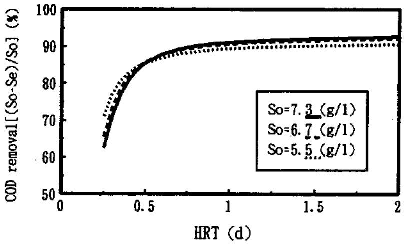


**Fig. 7-c** The effect of HRT on COD removal. (X=20 gVSS/l)

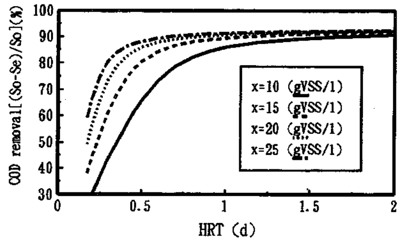


**Fig. 8** The effect of HRT on COD removal at each sludge concentration. ($S_o$=6.7 g/l)

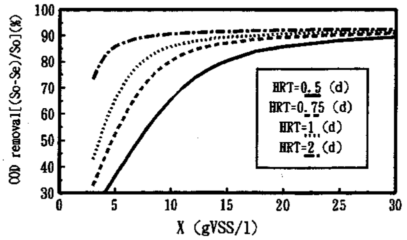


**Fig. 9** The effect of sludge concentration on COD removal at each HRT. ($S_o$=6.7 g/l)

**Table 3** Comparison of measured data in pilot plant with predicted data.

| Influent COD (g/l) | HRT (d) | Measured* COD (g/l) | Predicted** COD (g/l) | Error (%) |
|---|---|---|---|---|
| 6.77 | 1.0 | 0.716 | 75.7 | 8.2 |
| 7.29 | 0.75 | 0.928 | 81.5 | 12.5 |
| 5.53 | 0.75 | 0741 | 85 | -4.4 |

*: means effluent COD in pilot plant.

**: means effluent COD calculated by using the model.

$S_o$=6.7 g/l. In order to achieve 85% COD removal or more the following methods can be applied: a) HRT is high, so a low sludge concentration can be applied. It is obvious that this way is unreasonable. b) HRT is low, but a high sludge concentration has to be applied. However, a too high sludge concentration in the reactor the sludge circulation system can become blocked, and it is also unfavorable for separation of gas bubbles from sludge and for mixing of the influent and the biomass. In addition, the three-phase separator can become overloaded and the wash-out of sludge will be occurred. c) The proper HRT and sludge concentration are applied. **Fig. 8** and **Fig. 9** indicated that the optimum range of HRT is 0.75~1.0 day (18 ~24hr) , and the optimum range of X is 15~20 gVSS/l, respectively.

Those results were applied to the design of pilot plant. The operation of pilot plant was satisfactory, even organic loading rate of up to 13 kg COD/m$^3$/d, system achieved about 90% COD removal. **Table 3** showed the comparison of measured data in pilot plant with predicted ( simulated )data, and indicated that developed model can be used to predict the UASB performance for treating flax retting wastewater. Our understanding of the kinetics of flax retting wastewater treatment in the UASB process is still incomplete for engineering applications, and more research is necessary. That is , all of inferences need to be verified in full-scale plant.

## 7. CONCLUSIONS

The following are some of the conclusions that can be drawn from this study:

(1). The upflow anaerobic sludge blanket ( UASB ) system is effective in treating flax retting wastewater.

(2). Degradation of organic waste in the wastewater can be expressed by using modified Monod model. Kinetic parameters can be obtained by the curve fitting method, which were exhibited as following: maximum specific rate of substrate utilization, 1.085 ( gCOD/gVSS/d ); half-velocity constant, 0.433 ( g/l ); yield coefficient, 0.0649 ( gVSS/gCOD ) and decay coefficient, 0.0169 ( d$^{-1}$ ).

(3). When the concentration of the influent is at the range of 5.5~7.3 gCOD/l, the concentration of the hard-biodegradable materials ($S_n$) is 0.46 gCOD/l and the highest COD removal of flax retting wastewater is about 91.6~93.7%.

(4) The results of sensitivity analysis for model parameters showed that maximum specific rate of substrate utilization, $V_{max}$, is the most sensitive parameter, so it will has to be determined accurately in experiment.

(5). By using the developed model the optimum operating parameters of the UASB for treating flax retting wastewater are HRT of 0.75-1 day and X of 15-20 ( gVSS/l ).

## REFERENCES

1) McCarty, P. L.: One hundred years of anaerobic treatment. Anaerobic Digestion, D. E. Hughes et al (Eds.). Elsevien Biomedical Press , Amsterdam, pp.3-22, 1981.

2) Lettinga, G., van Velsen, A. E., Hobma, S. W., De Zeeuw, W. and Klapwijk, A.: Use of upflow sludge blanket (USB) reactor concept for bio-logical wastewater treatment, *Biotechnology and Bioengineering*, Vol.22, pp.699-734, 1980.

3) Lettinga, G.: High-rate anaerobic wastewater treatment using the UASB reactor under a wide range of temperature conditions, *Biotech. Eng. Reviews*, No.2, pp.253-284, 1984.

(4) Pipyn, P., Verstraete, W. and Ombregt, J. P.: A pilot scale anaerobic upflow reactor treating distillery wastewater, *Biotechnol. Letter*, No.1, pp. 495, 1979.

5) van der Meer, R. R. and Heertjes, P. M.: Mathematical description of anaerobic treatment of wastewater in upflow reactors, *Biotechnology and Bioengineering*, Vol.15, pp.2531-2556, 1983.

6) Bolle, W. L., van Breugel, J., van Eybergen, G. C., Kossen, N. W. F. and Zoetemeyer, R. J.: Modeling the liquid flow in up-flow anaerobic sludge blanket reactors, *Biotechnology and Bioengineering*, Vol.28, pp.1615-1620, 1986.

7) Hill, D. T.: Simplified Monod kinetics of methane fermentation of animal wastes, *Agricultural Wastes*, No.5, pp.1-16, 1983.

8) Pavlostathis, S. G. and Gosset, J. M.: A kinetic model for anaerobic digestion of biological sludge, *Biotechnology and Bioengineering*, Vol.28, pp.1519-1530, 1986.

9) APHA, AWWA and WPCF: Standard methods for the examination of water and wastewater, 15th edition. American Public Health Association, Washington D.C., 1980.

10) Morris ,G. R., Jewell, W. J. and Loehr, R. C.: Anaerobic fermentation of animal wastes: a kinetic design evaluation, In Proceedings of the Industrial Waste Conf., Environ. Sci. Div., Milwaukee, Wis., U.S.A., pp.689-700, 1977.

11) Heertjes, P. M. and van der Meer, R. R.: Dynamics of liquid flow in an up-flow reactor used for anaerobic treatment of wastewater, *Biotechnology and Bioengineering*, Vol.20, pp.1577-1594, 1978.

12) Harada, H., Momonoi, K., Ishihama, A. and Taneichi, N.: High rate treatment of wastewaters with self-immobilized methane fermentation reactor, *Proceedings of Environmental and Sanitary Engineering Research*, Vol.24, pp.241-251, 1988.

13) Bolle, W. L.: Kinetics of anaerobic purification of industrial wastewater, *Biotechnology and Bioengineering*, Vol.28, pp.542-548, 1986.

14) Buys, C., Heertjes, P. M. and van der Meer, R. R.: *Biotechnology and Bioengineering*, Vol.24, pp.1975-1989, 1982.

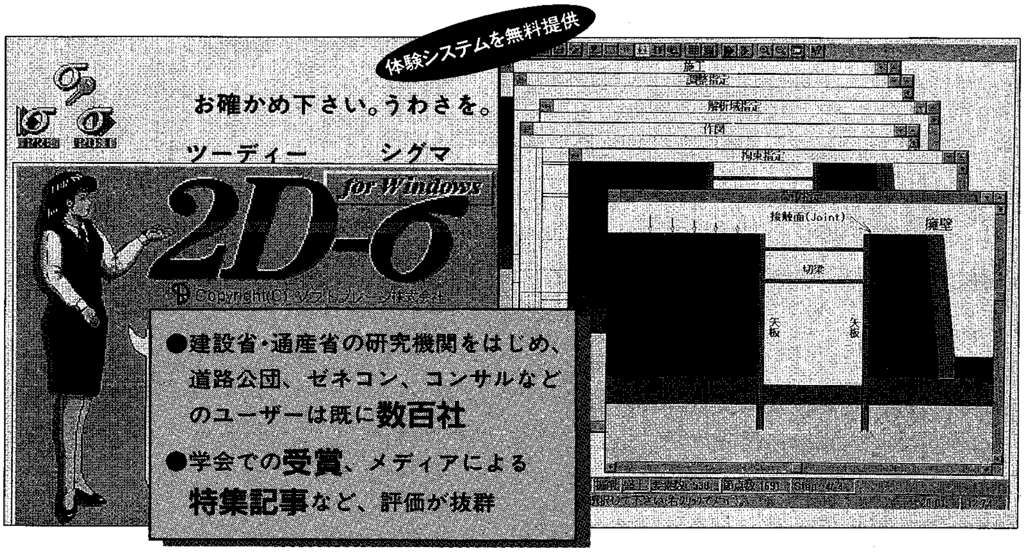
**(Received December 14, 1994)**

# 動力学的モデルによる亜麻廃液処理UASBの最適操作条件の検討

劉　軍・浮田正夫・中西　弘・今井　剛・深川勝之

ラボラトリープラントの実験結果をもとに簡単化された動力学的モデルを構築し，計算値と実測値の比較からその有用性について検討を行った．さらに動力学的解析を通してパイロットプラントの合理的な設計条件に関する検討を行った．実測値とモデルによる計算結果はほぼ一致し，本モデルの妥当性が示された．本モデルによる流入基質濃度が 5.5～7.3 g-COD/l（難分解性有機物 0.46 g-COD/l を含む）の実処理プラントの合理的な設計条件の設定およびその性能評価を行うことができ，本モデルは工学的な有用性を有すると考えられる．

# 世界をリードする夢の土木構造解析システム



●建設省・通産省の研究機関をはじめ、道路公団、ゼネコン、コンサルなどのユーザーは既に**数百社**

●学会での**受賞**、メディアによる**特集記事**など、評価が抜群

## 斬新なコンセプトと驚異の自動化・高速化・大容量。

大型機で数日間かかった解析がパソコンでわずか数十分間で／ 有限要素を意識せず、誰でも、どこでも、低コストで簡単に／ 一般技術者のノートPCによる現場解析も楽々／

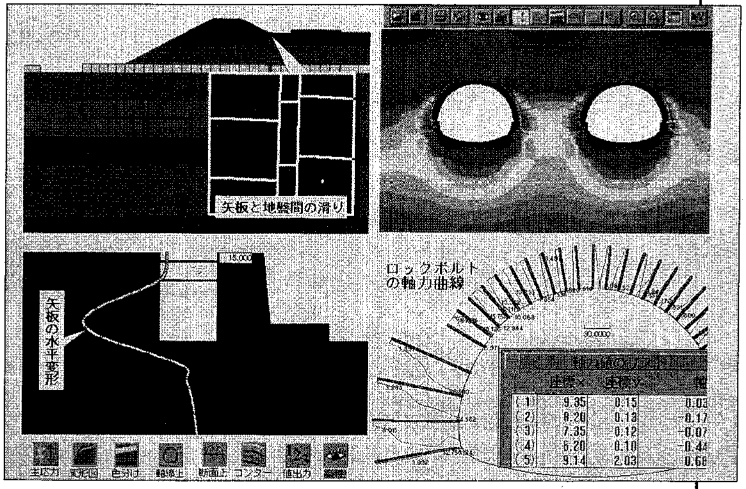
■有限要素の概念は一切表に出ない。解析の条件とプロセスを内蔵の高性能CADで作成した図面へ直感的に与えるのみ。

　土木構造解析特有の面倒な解析に特に有効(ステップ施工、掘削、盛土、支保・近接・拡幅、接触問題など)

■膨大な解析容量(1万節点以上)と驚異の演算速度(たとえば5000節点前後の解析は66MhzのPCでも2、3分間で完了。)

■豊富な入出力画面に編集を加え、説明文やキャプションを付けた上、ワンタッチで高品質の最終成果物が得られる。ワープロや表計算などの他のソフトにも図面と数値を転送できるので設計技術者が夢見る調査・設計・評価の一括自動化を実現。

■土木解析に必要な機能のほとんどに対応(非線形、弾塑性、接触面・弱面、熱応力、地震慣性力、自動ステップ解析、掘削、盛土)



| | 座標x | 座標y | |
|---|---|---|---|
| (1) | 9.35 | 0.15 | 0.03 |
| (2) | 8.20 | 0.13 | -0.17 |
| (3) | 7.35 | 0.12 | -0.07 |
| (4) | 6.20 | 0.10 | -0.44 |
| (5) | 9.14 | 2.03 | 0.68 |

土木業界で大好評

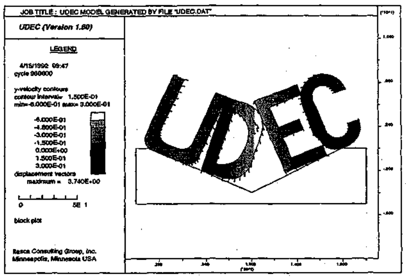
詳細資料提供

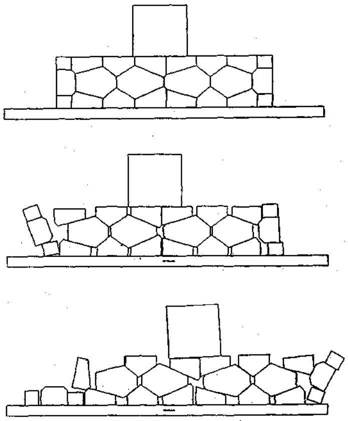
開発・販売　**ソフトブレーン(株)**　お問合せは 03-3592-7659

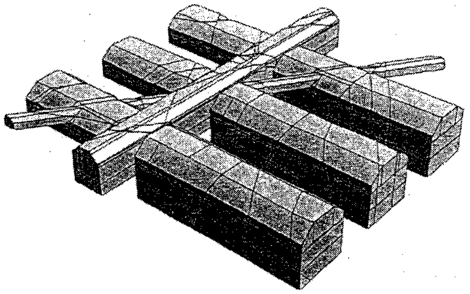
本社：〒001 札幌市北区北37条西4丁目 王陽ビル　Tel 011-736-7009　Fax 011-736-7449

# 個別要素法プログラムシリーズ

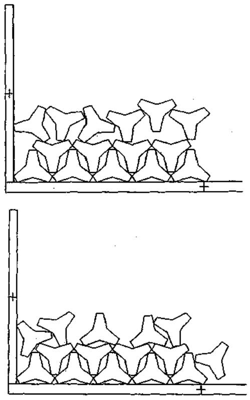
■開発元　Dr.Cundall（ITASCA社）



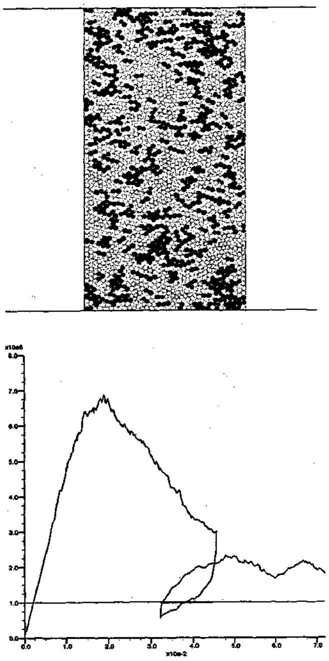




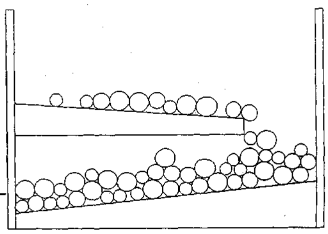
3DEC



BFLOW



PFC-2D



BALL-Poly

## ■価　格

●ロード・モジュール

| | | |
|---|---|---|
| ・UDEC | SUN/IBM-PC（標準バージョン） | 110万円 |
| | （Barton-Bandis Optionを含む場合） | 160万円 |
| ・3DEC | SUN/IBM-PC | 550万円 |
| ・PFC-2D | SUN/IBM-PC | 70万円 |

●ソース・コード

| | | |
|---|---|---|
| ・UDEC | SUN/IBM-PC（標準バージョン） | 190万円 |
| | （Barton-Bandis Optionを含む場合） | 240万円 |
| ・BFLOW | SUN | 190万円 |

プログラムはいずれも最新バージョンを提供いたします。また、問題に応じたプログラムの開発も行っています。

＊当社は1988年7月からITASCA社の販売代理店をしています。

*OKL* 株式会社 **応用工学研究室**

TEL.03-3437-2164　FAX.03-3437-2652
〒105 東京都港区虎ノ門5-1-4 東都ビル6F
㈱システムネットワーク内

# 地盤の非線形解析プログラム

■開発元　Dr.Cundall（ITASCA社）

# FLAC-2D/3D (Fast Lagrangian Analysis of Continua)

1950年代に有限要素法が出現し、コンピュータの発展と共に進歩をとげていったのと並行して、衝撃分野での解析を目的に始まった差分法に基づく、“Hydrocodes”もすくなからぬ成功をおさめていました。応力波伝播を基本とする弾塑性固体の大変形、スライド・ライン手法による滑り・剥離挙動の解析には目覚ましいものがありました。しかし、これらを取り扱うプログラムの多くは公的機関での開発のため公開されたものは余りありませんでした。FLACはこの流れをくむ地盤非線形解析プログラムです。

## プログラムの特徴

- 幾何学的大変形及び材料非線形を取り扱うことができます。陽解法のため歪み軟化解析が容易です。
- 複雑な３次元地盤をモデル化するため、優れたジェネレーター機能をそなえています。
- 機能追加のための開発ツールFISHプログラミング言語を備えていますので、機能追加が容易です。

## 要素ライブラリー

- ２次元平面歪／応力要素（2D）
- ソリッド要素（3D）
- ビーム要素（2D）
- ロックボルト要素（2D，3D）

## 適用分野

- 斜面・盛土の設計及び安定解析
- アースダム及びコンクリートダム解析
- トンネル、鉱山掘削解析
- 地下水、圧密、液状化解析（2D）

## 構成則

- 等方性、非等方性弾性
- 弾塑性（Mohr−Coulomb, Drucker−Prager）
- 偏在ジョイント・モデル（Ubiquitous joint）
- 歪ー硬化／軟化　●ヌル要素
- 液状化FINNモデル（2D）等

その他の構成則の機能追加も可能です。

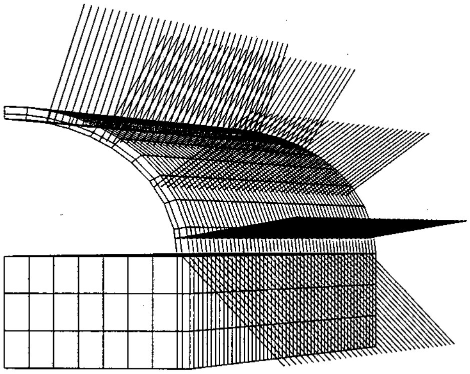
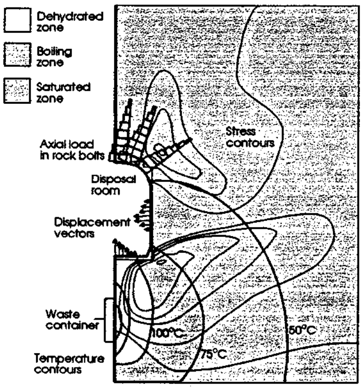


*Figure 5* **Steel bolt pattern for Method 2**



*Thermomechanical conditions five years after nuclear waste emplacement.*

## ■価　格（ロード・モジュール）

- FLAC-2D　SUN/IBM-PC（標準バージョン）……………………………80万円
  （Dynamic, Creep, Thermal Optionを含む場合）……110万円
- FLAC-3D　SUN/IBM-PC（Creep Optionを含む）…………………190万円

プログラムはいずれも最新バージョンを提供いたします。また、問題に応じた地盤非線形プログラムの開発も行っています。

＊当社は1988年7月からITASCA社の販売代理店をしています。

*OKL* 株式　研究室

TEL.03-　437-2652

〒105 東　ビル6F

パソコン用、準3次元広域地下水変動解析プログラム

未来設計企業 CRC

# PC/UNISSF Ver.3.0 for Windows

"PC/UNISSF Ver.3.0"は、すでに汎用機やEWSで実績のある準3次元広域地下水変動解析プログラム、UNISSF(V-2)に強力なプリ・ポスト処理プログラムを付加し、Windows版として新登場しました。このプリ・ポストプログラムは、マウスを使ったメニュー形式の導入、画面上での入出力等の機能により、すぐれた操作性をもたらします。

新登場!

## プログラムの特徴（☆印は新機能）

### ■プリ処理

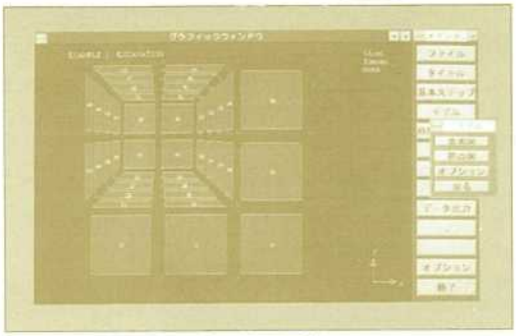
☆モデル作成のためのメッシュジェネレート機能
★地層データ、初期水位データ等の自動発生機能
☆モデル図を参照しながら、境界条件等各種データの入力、修正が可能
☆マウス入力とメニュー形式による操作性の向上

### ■解析機能

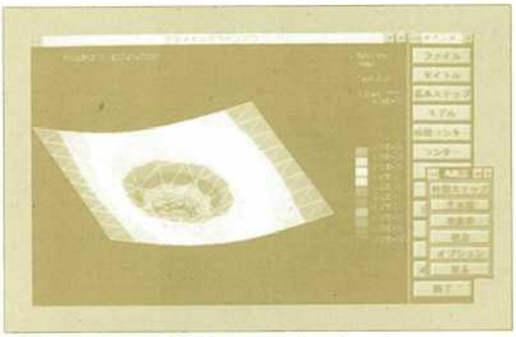
☆汎用機、EWS版と同一機能（順解析）、同一データフォーマット
☆約3000～10000節点までのモデルが解析可能
★降雨・揚水井・浸出面の取り扱いが可能
★水位・流量の経時変化
★境界条件の変更、材質の変更
★掘削機能・簡易漏水機能
★初期定常計算・非定常計算・最終定常計算

### ■ポスト処理

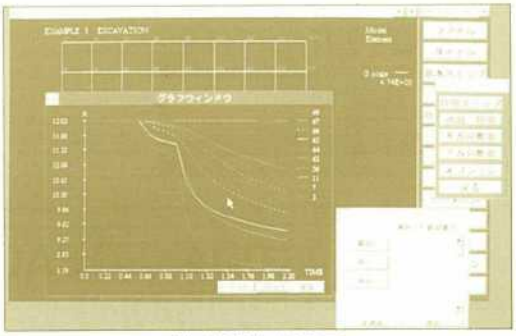
☆線画に加えて画面塗りつぶし処理が可能
☆水位の時間変化が簡単にグラフ化可能
☆マウス入力とメニュー形式による操作性の大幅な向上



【モデル図】



【全水頭コンター】



【水位変化グラフ】

**動作環境**
Windows Ver.3.1
CPU：80386 以上（推奨 80486DX 33MHz以上）
RAM：8MB 以上
ハードディスク空容量：10MB以上

・UNISSFは情報処理振興事業会の委託を受けて当社で開発したプログラムです。
・Windowsは米国マイクロソフト社の商標です。

問い合わせ先
**株式会社CRC総合研究所**
**西日本事業部 科学システム営業部**
〒541 大阪市中央区久太郎町4-1-3
TEL.06-241-4730（担当／岩崎）

通商産業省　特別認可法人
**情報処理振興事業協会（IPA）**
〒105 東京都港区芝公園3丁目1番38
TEL.03-3437-2301

昭和三十七年五月二十八日 第三種郵便物認可
平成七年八月十五日・印刷
平成七年八月二十一日・発行
土木学会論文集（毎月一回二十日・二十一日発行）

定価＝一、五〇〇円（本体価格・一、四五六円）