8. POSVETOVANJE SLOCOLD

AKTUALNE TEME V PREGRADNEM INŽENIRSTVU

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zbornik prispevkov

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Andrej Kryžanowski

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8. POSVETOVANJE SLOCOLD, AKTUALNE TEME V PREGRADNEM INŽENIRSTVU

ZBORNIK PRISPEVKOV

Andrej Kryžanowski, Andrej Sedej (urednika)

izdal: Slovenski nacionalni komite za velike pregrade – SLOCOLD

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UVOD

Letošnje, osmo strokovno posvetovanje SLOCOLD smo posvetili predstavitvi aktualnim inženirskim problematikam, s katerimi se vsakodnevno srečujemo pri načrtovanju in upravljanju velikih pregrad. Ob tej priložnosti smo gostili tudi kolege iz Makedonskega komiteja za velike pregrade (MAKOLD) in jih povabili, da predstavijo svoje poglede in pristope reševanja problematike varnosti velikih pregrad.

V zborniku prispevkov strokovnega posvetovanja se prepletajo tematike: varnost pregrad, zagotavljanja varnosti objektov ter ekološki problemi, teme, ki so postale v zadnjem času stalnica predstavitve dela članov komiteja. V uvodnem prispevku je predstavljena metodologija določevanja potresnih parametrov za analizo potresne varnosti velikih pregrad (G. Stomatovska). V prispevku avtorjev, V. J. Mircevske, V. Bičkovski in M. Garevski je predstavljen primer modeliranja nelinearnega obnašanja skalometne pregrade pri dinamičnih obremenitvah. Sledi prispevek avtoric, N. Smolar, A. Rejec s prikazom povzetka presoje vplivov na okolje za črpalno HE Avče. V prispevku A. Sedeja je prikazan primer uporabe programskega orodja za izdelavo preliminarne ocene širjenja koncentracije snovi v recipientu. V zaključnem delu zbornika pa avtorji, P. Sinčič, R. Vidrih, M. Godec in M. Gostinčar predstavljajo posodobitev sistema potresnega opazovanja pregrade Vogršček v skladu z novo regulativo.

Na tem mestu se ponovno zahvaljujem vsem referentom ter kolegom iz MAKOLD, ki so s svojimi prispevki na posvetovanju omogočili pripravo tega zbornika. Zahvala gre tudi vsem ostalim kolegom (M. Brenčič, D. Ciuha, M. Komel, P. Blažej, A. Rejec), ki so ustno podali prispevke na posvetovanju. Posebno zahvalo naslavljam tudi na naše kolektivne člane, ki s podporo omogočajo strokovno delo našega društva, brez katere tudi ne bi mogli pripraviti letošnjega zbornika tako po vsebini, kot v obliki, ki je pred vami.

predsednik SLOCOLD:

mag. Andrej Kryžanowski

Nova Gorica, 7. maj 2006

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VSEBINA

SEISMIC SAFETY OF STRUCTURES

CASE STUDY: PROBABILISTIC METHODOLOGICAL APPROACH TO DEFINITION OF SEISMIC INPUT

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ABSTRACT

A methodological approach to definition of seismic input for seismic safety analyses of structures is presented in this paper. Recorded accelerogrammes of occurred strong earthquakes have been used as seismic input, while their participation in the seismic safety of structures has been defined based on the seismic activity of the seismic sources around the considered site. The developed methodological approach is probabilistic and it includes treatment of uncertainties of used attenuation laws. Four probabilistic distributions: normal, limited normal, triangular and beta have been used for treatment of uncertainties. The methodological approach has been verified on a hypothetical location in Republic of Macedonia.

1. INTRODUCTION

The application of recorded accelerogrammes in analyses of seismic safety of structures is a common practice all over the world. The application of recorded accelerogrammes in description of seismic effect is also recommended by modern concepts of seismic design codes as is Eurocode 8 (Chapter 3.2.3.2 – Alternative presentation of seismic action in European Standard prEn 1998-200X, Doc CEN/TC250/SC8/N317, Draft from January 2003). In accordance with the recommendations, clause 3.2.3.2 (1)P, the recorded accelerogrammes should comply with the seismogene characteristics of the seismic sources and the corresponding characteristics of the local soil at the site of the structure.

2. METHODOLOGICAL APPROACH

2.1 Theoretical Background

The record of an occurred earthquake taken on a location at a certain epicentral/or hypocentral distance from the epicenter in certain soil conditions is represented by a random vector, which is in function of three random variables: magnitude, distance and local soil conditions. For accelerogrammes recorded in the same type of soil conditions the problem becomes two-dimensional and is presented by the following relation for two-dimensional vector:

$$\bar{X} = (X_1, X_2)$$

where X_1 and X_2 are independent discrete random variables, magnitude and distance, respectively. Since the values of X_1 and X_2 represent events that can take place, there are probabilities associated with any pair of values x_1 and x_2. The probabilities for all possible pairs of x_1 and x_2 may be described by a joint probability distribution function of the random variables X_1 and X_2, defined as

$$F_{X_1,X_2}(x\ ,x_2) = P(X_1 \le x_1; X_2 \le x_2)$$

which is the cumulative probability of the joint occurrences of the events identified by $X_1 \le x_1$ and $X_2 \le x_2$. The joint probability distribution function is a nonnegative and a non-decreasing function of X_1 and X_2 , and it also satisfies the axioms of probability.

Because the random variables X_1 and X_2 are discrete, the probability distribution may also be described by the joint probability mass function –PMF, which is simply:

$$p_{X_1,X_2}(x_1, x_2) = P(X_1 = x_1; X_2 = x_2)$$

Then the probability distribution function becomes:

$$F_{X_1,X_2}(x_1,x_2) = \sum_{(x_{1i} i \le x_1; x_{2i} \le x_2)} p_{X_1X_2}(x_1,x_2)$$

The probability mass function of the individual random variable is the so called marginal probability mass function and may be obtained from the joint probability mass function -JPMF, or:

$$p_{X_1}(x_1) = \sum_{all\ x_{1i}} p_{X_1,X_2}(x_1,x_2)$$

$$p_{X_2}(x_2) = \sum_{all\ x_{2i}} p_{X_1,X_2}(x_1,x_2)$$

2.2 Treatment of Uncertainties

Treatment of uncertainties is a very important problem for all random processes and it has very big influence on the final results. To treat the uncertainties in the attenuation laws, four distributions have been used in this investigations as follows: normal, limited normal, beta and triangular. The median curve of the attenuation law has the following form:

$$\ln A' = b_1 + b_2 m + b_3 \ln(R_h + c)$$

where: A' - median horizontal peak ground acceleration; m - Richter magnitude; R_h - hypocentral distance in km.; c - constant; b_1, b_2, b_3 - regression coefficients. The uncertainty is presented by the standard deviation ξ. The probabilistic characteristics of used distributions are shown in Table 1. In each probability density function -PDF

$$x = \frac{\ln A - \ln A'}{\xi}$$ where A- horizontal peak ground acceleration.

Table 1 Probabilistic characteristics of univariate distributions

Distribution	Probability density function-PDF
Normal	$f(x) = \frac{1}{\sqrt{2\pi}\xi} \exp\left[-\frac{1}{2}x^2\right]$ $\quad -\infty \le x < \infty$
Limited Normal	$f(x) = \frac{1.0027}{\sqrt{2\pi}\xi} \exp\left[-\frac{1}{2}x^2\right]$ $\quad -3 \le x \le +3$
Beta	$f(x) = (5\times10^{-4})(x+3)^3(3-x)^3$ $\quad -3 \le x \le 3$

	$f(x)=0$	$-3>x>3$
Triangular	$f(x)=\frac{x+c}{c^2}$	$-c\le x\le 0$
	$f(x)=\frac{c-x}{c^2}$	$0\le x\le c$
	$f(x)=0$	$-c>x>c$
	$c=\sqrt{6}$	

2.3 Steps in the Methodological Approach

The spatially distributed seismic sources around the considered site are represented by their geometrical shapes. The area of each seismic source is divided into a certain number of seismic sub-sources. The position of each sub-source is defined by its center of gravity. Each seismic source generates seismic activity which is in function of the minimal and the maximal magnitude expected at the seismic source. The magnitude range of $M_{low}=M_{\min}$ to $M_{upper}=M_{\max}$ of each seismic source taken separately is divided into a certain number of magnitude intervals with a step of ΔM. In this way, there are obtained the elementary sub-sources with a defined area and seismic activity in function of the step. The seismic activity of the sub-source is indicated by λij where i is the number of the sub-source, while j is the number of the magnitude interval.

The attenuation of amplitudes of ground motion parameters from the seismic sub-source to the location is represented by ground motion models referred to as attenuation laws, i.e., ground motion models for corresponding types of soil.

Each elementary sub-source with its seismic activity λij is at epicentral distance R_e^i and causes or does not cause a certain value of the ground motion parameter at the considered site. Depending on whether a certain value of the ground motion parameter of the site is exceeded or not the seismic activity can be classified into a seismic activity that induces and a seismic activity that does not induce a certain value of the ground motion parameter at the site. The seismic activities inducing exceedence of a defined value of the ground motion parameter at the site are of engineering interest. The authors call this seismic activity an effective seismic activity. The classification of the epicentral distances between the lowest value – $R_{\min}$ and the highest value $R_{\max}$ into subgroups with constant or variable step -ΔR leads to obtaining of the distribution of the effective seismic activity from the seismic sources around the considered location into elementary parts with a size of ΔR and ΔM.

Obtained in this way are the elementary sub-sources of epicentral/or hypocentral distances distributed between $R_{\min}$ and $R_{\max}$. From such a distribution, the percentage of participation of each pair (M, R) in the seismic safety analysis of the structure at the considered site can be computed, i.e., the

joint probability mass function for two-dimensional random vector is defined in function of the discrete random variables magnitude and distance. The marginal probability mass functions for epicentral distance and earthquake magnitude are also defined.

Schematic presentation of the developed methodological approach is presented in Fig. 1.

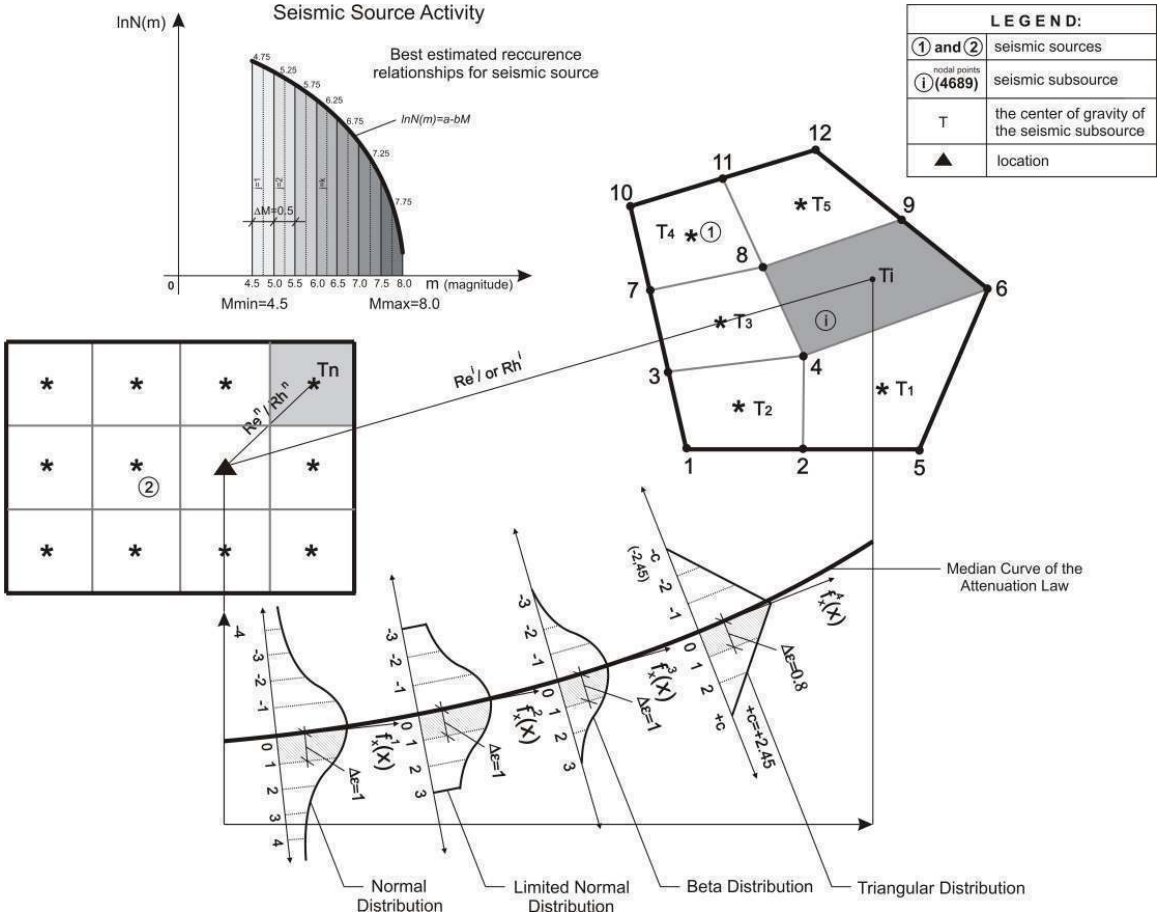


Figure 1 Schematic presentation of the developed methodological approach

2.4 Verification of the Methodological Approach

A hypothetical location in R. Macedonia has been considered. For the seismicity of Republic of Macedonia, there have been used the results from previous investigations /5/ in which, based on detailed seismological and other investigations related to the conditions for occurrence of earthquakes, there have been defined the models of seismic sources in Republic of Macedonia and the boundary areas with the neighboring countries as well as the empirical relationships between number of earthquakes with certain magnitude and the magnitude known as recurrence relationships.

The spatial distribution of seismic sources is represented by a mathematical model of seismic sources.

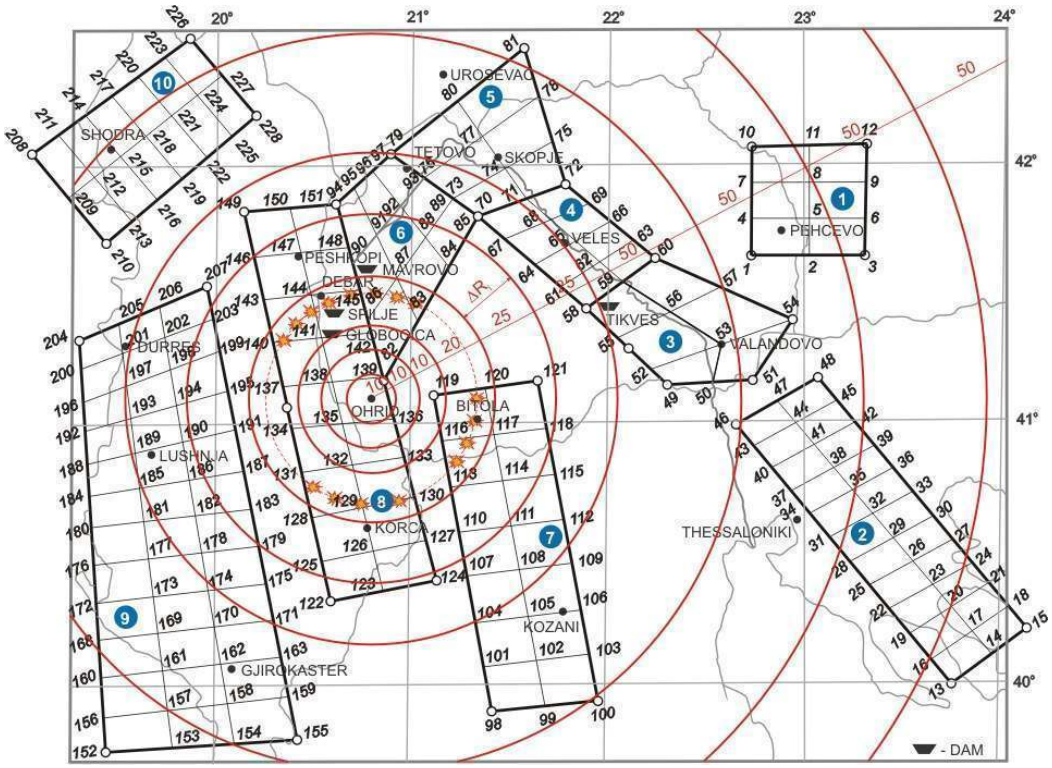


Figure 2 Model of the seismic sources and sub-sources

Each of the 10 defined seismic sources has been divided into a certain number of seismic sub-sources as follows 6, 22, 6, 8, 6, 9, 14, 18, 39 and 12, respectively for the seismic sources from 1 to 10 (Fig. 2) or 140 sub-sources with a total of 228 nodal points. For each seismic sub-source, the magnitude is divided into sub-intervals with $\Delta M = 0.5$, starting with $M \leq 4.5$ to $M \leq 8.0$. A set of 768 elements has been obtained. Applying the distributions for the scatter of data around the computed median values described in Chapter 2.2, for the PGA > 100cm/s2 and PGA>300 cm/s2, there have been defined the joint probability mass function-JPMF and the marginal probability mass functions-MPMF separately for epicentral distance and local Richter magnitude. Also, the so called reference earthquake can be obtained on the basis of the marginal probability mass functions for each case of the PGA.

2.5 Obtained Results and Discussion

The values of the joint probability mass functions are presented in Table 2 and Table 3. Each table box contains four values. They are obtained by using normal, beta, triangular and limited normal distribution, downwards, respectively. The obtained results (Table 2 and Table 3) show that the application of limited normal, beta and normal distribution for values of ε ranging from –3 to + 3 yields very similar results. There is deviation of values in the triangular distribution because $\varepsilon = \pm\sqrt{6}$ and because it has a mathematically defined probability density function-PDF which is not suitable for treatment of uncertainties in engineering problems. The investigations have confirmed that the normal distribution and the limited normal distribution ranging from –3 to +3 correspond to treatment of uncertainties of engineering problems. The application of limits wider that those applied on these two distributions are recommended by the

author for cases when higher values of ground motion parameters are expected on the considered location. In this investigation, it has also been confirmed that the beta distribution which is also referred to as engineering distribution within the limits of –3 to + 3 corresponds to treatment of uncertainties in engineering problems.

Table 2 Values of the joint probability mass function for PGA>100 cm/s^2

Magnitude M	0-10	10-20	20-30	30-50	50-75	75-100	100-150	150-200	200-250	250-300
4.5-5.0	4.26 4.58 6.31 4.26	4.26 4.58 6.31 4.26	8.51 9.16 12.62 8.51	11.49 11.86 10.94 11.49	6.70 5.90 1.07 6.70	1.27 1.11 0. 1.17				
5.0-5.5	4.75 4.52 4.91 4.75	4.75 4.52 2.22 4.75	3.00 3.23 4.45 3.00	9.70 10.43 9.47 9.70	2.89 2.66 5.96 2.89	4.18 3.67 0. 4.17	0.30 0.26 0. 0.30			
5.5-6.0	1.67 1.59 1.73 1.67	1.67 1.59 1.73 1.67	3.35 3.19 3.46 3.35	3.43 3.68 5.01 3.43	3.43 3.51 2.67 3.34	1.51 1.33 3.25 1.51	1.78 1.57 0.35 1.78			
6.0-6.5	0.99 0.88 0.94 0.99	0.58 0.56 0.61 0.59	1.18 1.12 1.22 1.18	2.91 2.82 2.84 2.91	2.19 2.35 2.91 2.19	2.34 2.46 1.56 2.34	1.07 0.94 1.57 1.07	0.22 0.19 0. 0.22		
6.5-7.0	0.31 0.27 0.29 0.31	0.31 0.27 0.29 0.31	0.36 0.35 0.58 0.36	1.09 1.04 1.02 1.09	0.93 0.96 1.78 0.93	1.37 1.47 1.47 1.37	1.16 1.20 1.07 1.16	0.16 0.14 0.04 0.16	0.01 0.01 0. 0.01	
7.0-7.5									0.01 0.01 0. 0.01	
7.5-8.0									0. 0. 0.01 0.	

Table 3 Values of the joint probability mass function for PGA>300 cm/s^2

	EPICENTRAL DISTANCE - R (km.)									
Magnitude M	0-10	10-20	20-30	30-50	50-75	75-100	100-150	150-200	200-250	250-300
4.5-5.0	16.49 15.29 0. 16.49									
5.0-5.5	5.81 5.39 22.08 5.81	5.81 5.39 0. 5.81	11.62 10.77 0. 11.62	0.37 0.34 0. 0.37						
5.5-6.0	15.01 17.02 7.78 15.02	2.05 1.90 7.78 2.05	4.10 3.80 15.56 4.10	6.95 6.44 0. 6.95						
6.0-6.5	5.29 6.0 10.97 5.29	5.29 6.0 2.74 5.29	1.44 1.34 5.48 1.44	4.55 4.22 9.05 4.54	1.88 1.74 0. 1.88					
6.5-7.0	1.63 1.85 3.38 1.63	1.63 1.85 3.38 1.63	3.26 3.69 6.76 3.26	4.15 4.52 5.06 4.15	2.66. 2.47 0. 2.66					
7.0-7.5										
7.5-8.0										

To point to the great importance of treatment of uncertainties in general and particularly the attenuation laws, Table 4 shows the results obtained when uncertainties are not treated in the attenuation laws, or $\varepsilon = 0$. In each box of Table 4, downwards, the first value refers to PGA>100 cm/s^2 and $\varepsilon = 0$, while the second refers to PGA > 300 cm/s^2 and $\varepsilon = 0$, which means that the median value of the attenuation law will exceed the mentioned values on the considered site. The results presented in Table 4 have shown that the median of the attenuation law can exceed 100 cm/s^2 on the considered location, which is not the case with 300 cm/s^2. The third value in each box of Table 4 is obtained by

use of the attenuation law as a median plus one standard deviation, for PGA > 300 cm/s^2.

The comparison of the first value in each box in Table 4 and the values from the corresponding box in Table 2 (case PGA > 100 cm/s^2), as well as the comparison of the second value in each box in Table 4 and the values in the corresponding box in Table 3 (case PGA > 300 cm/s^2) clearly point to the size of errors made when uncertainties in the attenuation laws are not treated in the investigation for determination of seismic input in seismic safety analyses of structures and seismic hazard analyses of the considered site when methodologies that do not include standard deviation are applied. The application of attenuation laws applied as median plus standard deviation through change of regression coefficients for the value of the standard deviation does not mean included standard deviation in seismic hazard analyses.

Table 4 Values of the joint probability mass function (PGA>100 cm/s^2 and ε =0.; PGA>300 cm/s^2 and ε =0.; PGA>300 cm/s^2 and ε =1)

		EPICENTRAL DISTANCE - R (km.)									
		0-10	10-20	20-30	30-50	50-75	75-100	100-150	150-200	200-250	250-300
Magnitude M	4.5-5.0										
	5.0-5.5										
	5.5-6.0	31.55 0. 0.									
	6.0-6.5	11.12 0. 0.	11.12 0. 0.	22.24 0. 0.							
	6.5-7.0	3.42 0. 50.	3.42 0. 50.	6.85 0. 0.	10.27 0. 0.						
	7.0-7.5										
	7.5-8.0										

The graphical presentation of the results obtained for PGA>100cm/s2 is given in Figures 3 to 5. The reference earthquake for same PGA has magnitude M=5.35 and epicentral distance Re=43km. The epicentral distance of this earthquake is indicated by stars in Figure 2. A selection of an accelerogram with the characteristics of the reference earthquake for analysis of seismic safety means acceptance that the entire seismicity around the location of the structure is represented by it or its participation in the analyses by 100%.

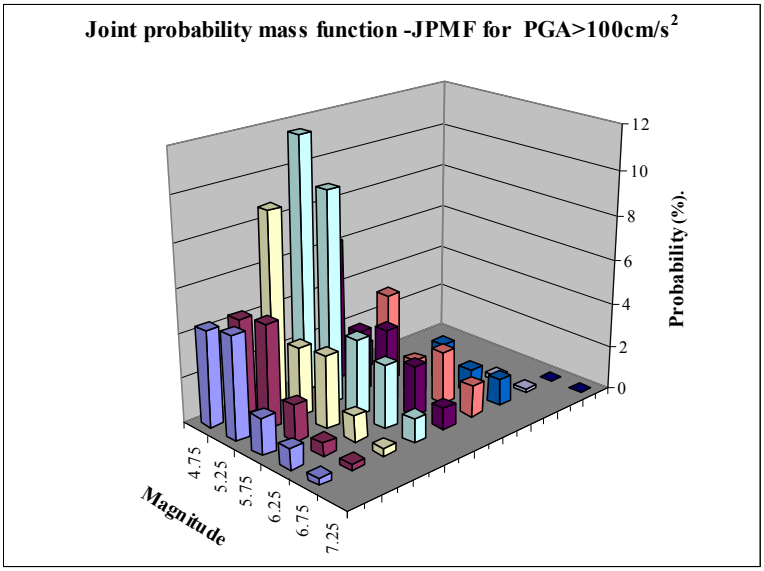
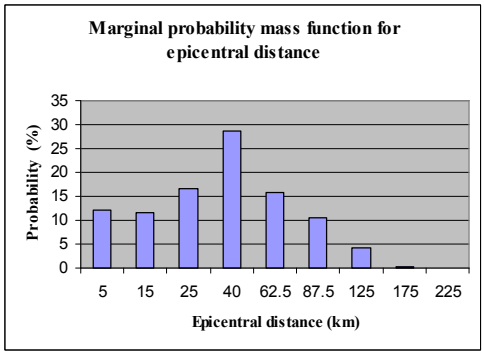


Figure 3 The graphical presentation of the results obtained for PGA>100cm/s^2



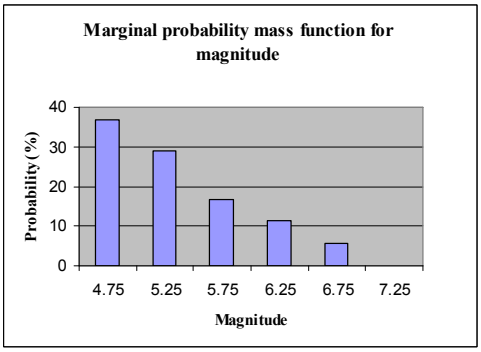


Figure 4 and Figure 5 The graphical presentation of the results obtained for PGA>100cm/s^2

2.6 Application of the methodological approach

The results from these investigations can be applied in selecting actual accelerogrammes for analyses of seismic safety of both existing structures and structures under design.

The methodological approach presented in this paper is of particular importance for definition of seismic safety of structures designed in compliance with the existing regulations for seismic design that are of an older date and based on a deterministic approach which structures will be exposed to seismic effect in accordance with the seismic activity of Republic of Macedonia applied by use of a probabilistic approach.

The methodological approach can also be used while selecting actual accelerogrammes for seismic safety analyses of structures designed in compliance with the new codes for seismic design as is EUROCODE 8 in which the design spectrum (elastic or inelastic), or the site specific spectra are defined based on seismic hazard analyses performed for the considered location with a

defined referent return period in years. In this case, the set of actual accelerogrammes is defined from the condition that these induce a value of spectral acceleration at the site of the structure greater than the design or site specific spectrum for a period equal to the natural period of vibration of the structure.

The deficiency of the methodological approach is that the local soil conditions at the site of the structure are not treated by a probabilistic approach, i.e., a random vector with three independent random variables: magnitude, distance and type of soil should be used in the investigations for selection of a real set of accelergorammes for seismic safety analysis of the structure.

3. CONCLUSIONS

The developed methodological approach provides great benefits regarding proper selection and use of records of occurred earthquakes (three-componental accelerogramems) in the analyses of seismic safety of structures. It also points out the size of the error made by the researchers who select one or several accelerogrammes without providing a corresponding proof for the selection made.

The methodological approach should also include treatment of uncertainties under the effect of the defined recurrent relations as lower, best and upper; the different attenuation laws, the variable values of ΔM and ΔR, and the local soil conditions.

Presented in this paper are the results that involve treatment of uncertainties under the effect of the attenuation laws only.

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ASSESSMENT OF DYNAMIC STABILITY OF ROCK-FILL DAM

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ABSTRACT

The risk of possible damage to large dams should be defined and reduced to minimum. It is therefore necessary to have adequate theoretical and experimental knowledge on the phenomena affecting their stability. Dams constructed of local materials are characterized by complex behavior and the most important feature is the non- linearity that is specially emphasized during strong excitations.

Treated in this paper is the problem of non-linear dynamic behavior of a rock-fill dam based on Mohr-Coulomb failure criterion. The dam is situated in a narrow “V” shape canyon. Therefore three-dimensional mathematical model is used, for the purpose that the theoretical achievements be brought closer to engineering practice. Automatic generation of the substructure type of model is created connecting the dam body with the topology of the terrain at the site.

Nonlinear Dynamic response is based on the direct "step by step" linear integration method. For the purpose of providing unconditional numerical stability, the Wilson-θ method with the value of constant θ=1.4 has been used.

Dynamic analysis output results are the following. Time histories of developed relative displacements and absolute accelerations and time histories of developed principal and component stresses for selected points of the model, comparing linear and nonlinear output results. Plastic deformation shapes for selected cross sections as well as presentation of plastic and tension cutoff zones. Also, defined are the time histories of coefficient of safety against sliding along the potential sliding planes, in the form of shells, in conditions of seismic effect. The generation of the sliding surfaces (the shells) is automatically done by providing of relevant data that define the form of the shell and its position in respect to the centre of the dam crest.

The drawings and the presented results are obtained using a genuine computer programme that is written for the WINDOWS operative system by use of FORTRAN 90, DIGITAL VISUAL FORTRAN compiler and library for graphic support PLOT88 for WINDOWS.

1. SELECTION OF THE MODEL FOR ANALYSIS

Distribution of stresses and strain in the dam body due to the action of static and dynamic forces is directly affected by the shape of the canyon where the dam is situated. Actually the selection of the type of dam that should be constracted is dependent on the quality of the foundation base as well as the geometrical proportions of the cayon site. If rock-fill dam is built in a narrow "V" shape of canyon, then only the main cetntral cross section acts in plane strain conditions. The closer the sections are to the abutments, the greater is the influence of both, boundary conditions and the decreased height of the sections in the respect to the central one, on the distribution of stresses and strains in them.

This results in deflection from plane strain state conditions followed by a decreased intensity of the spherical stress and hence reduced shear resistance of the soil in these parts of the dam. Therefore the behavior and the assesment of the stability of the central section based on plain strain analysis cannot be representative for the satbility of the whole dam. Application of the 3D matematical model that should be, from an engineering point of view, an adequate and correct aproximation of the real structure is becoming an imperative.

Automatic generation of 3D mathematical models has required a database on the topology of the terrain in the immediate vicinity of the dam foundation, the position of the axis of the dam crest at the base, fig. 1, and the shape of the characteristic central cross-section of the dam, fig. 2. The height of the dam is 126 m which classifies it into the category of high dams. The length of the dam along the crest axis is 300 m, the crest width is 10 m, the maximum width of the base is 496 m. The clayey core has a width of 6 m at the crest and a width of 63 m at the foundation. The clayey core is founded on bedrock. The inclination of the upstream and downstream slope is 1:2.2 and 1:2.0, respectively.

The database on the topology of the terrain has been created in a global coordinate system, digitalizing the izolines, so each izoline is presented with a series of equations of second order curves passing through three neighboring points on it. The main central cross section fig. 2, should be defined in its local coordinate system and should be divided into a certain number of substructures, describing in that way the zones of presence of different materials. The coordinates of any point that belongs to the plain model in respect to the global coordinate system "X_G-Z_G-Z_G" are defined by transformation of coordinates of the plain model on the local coordinate system "x_l-y_l-z_l" into the local coordinate system "X_L-Y_L-Z_L" whereat Y_{CL}=0, $X_{CL} \neq 0$ and Z_{CL} = 0 if the absolute Z coordinates are used in definition of the plain model.

$$\begin{Bmatrix} X_L \\ Y_L \\ Z_L \end{Bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} x_l \\ y_l \\ z_l \end{Bmatrix} + \begin{Bmatrix} Y_{CL} \\ X_{CL} \\ Z_{CL} \end{Bmatrix}$$

and transformation of the coordinates from the local system "X_L-Z_L-Z_L" into the global system "X_G-Z_G-Z_G", whereat coordinate X_L = 0.

$$\begin{Bmatrix} X_G \\ Y_G \\ Z_G \end{Bmatrix} = \begin{bmatrix} C & -S & 0 \\ S & C & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} X_L \\ Y_L \\ Z_L \end{Bmatrix} + \begin{Bmatrix} X_C \\ Y_C \\ Z_C \end{Bmatrix}$$

At each altitude, the coordinates of characteristic intersection points with the boundary lines of the plain model are defined, fig. 2. Drawn through these points are straight lines parallel to the dam crest axis. So obtained in this way are the cross sections of the dam body with the terrain at each altitude, as presented in fig. 3. For definition of the 3D model adopted for the analysis we should select only the characteristic cross sections, otherwise we will have a considerably dense substructure and F.E. mesh, that will result in an increased value of matrix band. Fig. 4. provides a cumulative presentation of only selected horizontal cross sections that are used for definition of the 3D mathematical model presented in fig. 5. The program further performs automatic generation of F.E. mesh with reuired density. It also, automatically links the substructures which results in a certain initial value of the matrix band. Elaborated is a subroutine for reducing the band by 20% . The adopted 3D mathematical model has a total number of substructures of 212, external substructures' nodes of 6250 , internal substructures' nodes of 2122 and matrix band of 2700.

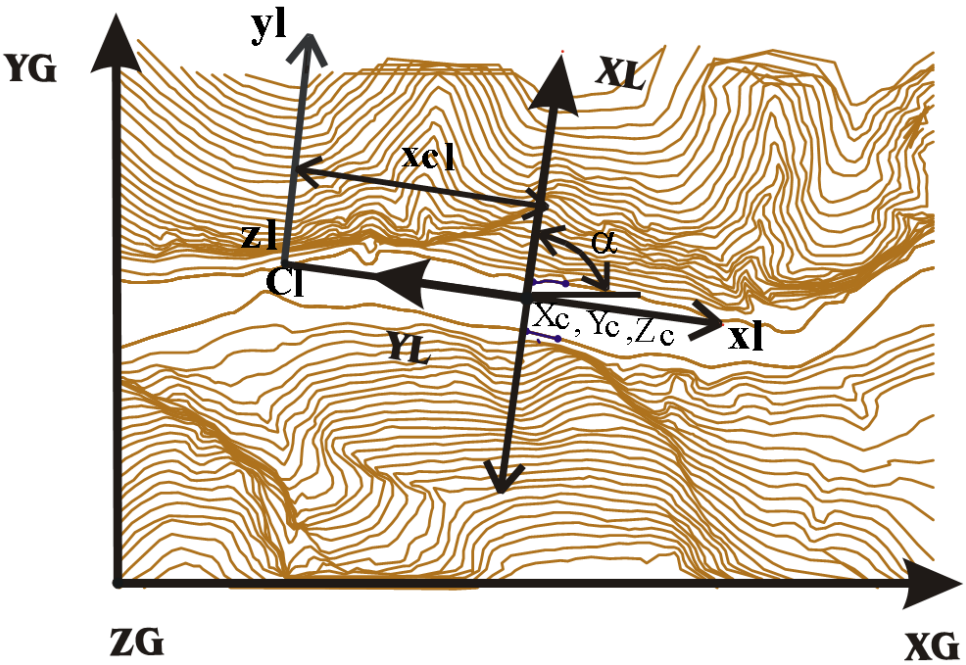


Figure 1 Schematic presentation of the required position of the dam body with indication of individual coordinate systems and relevant data

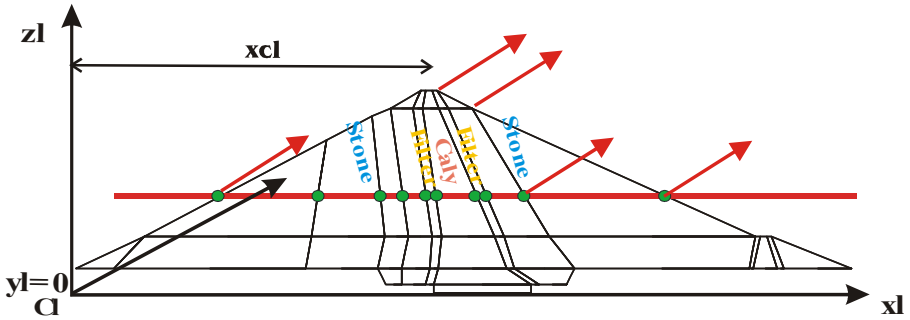


Figure 2 Central cross-section with zones of presence of different materials

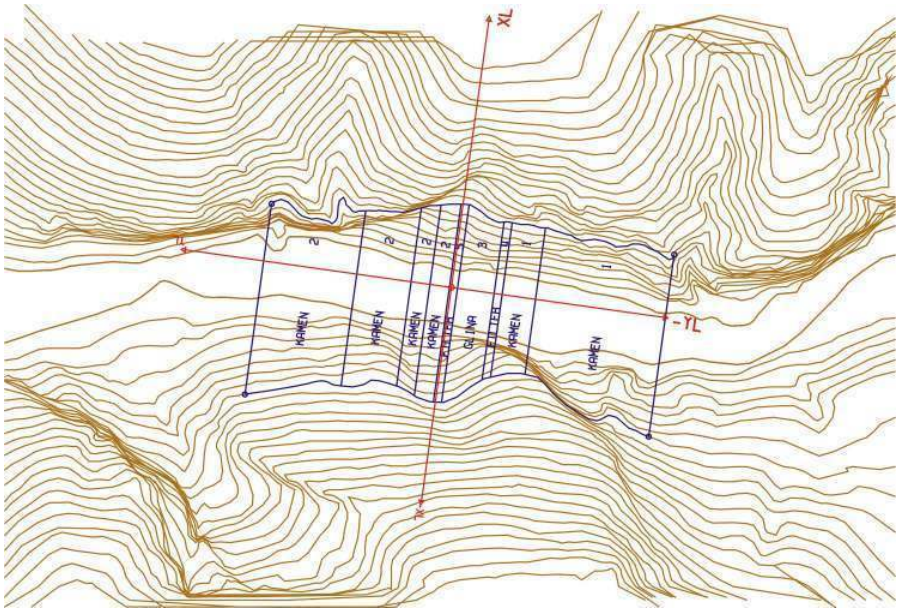


Figure 3 Cross-section of the the dam body with the terrain at altitude 405

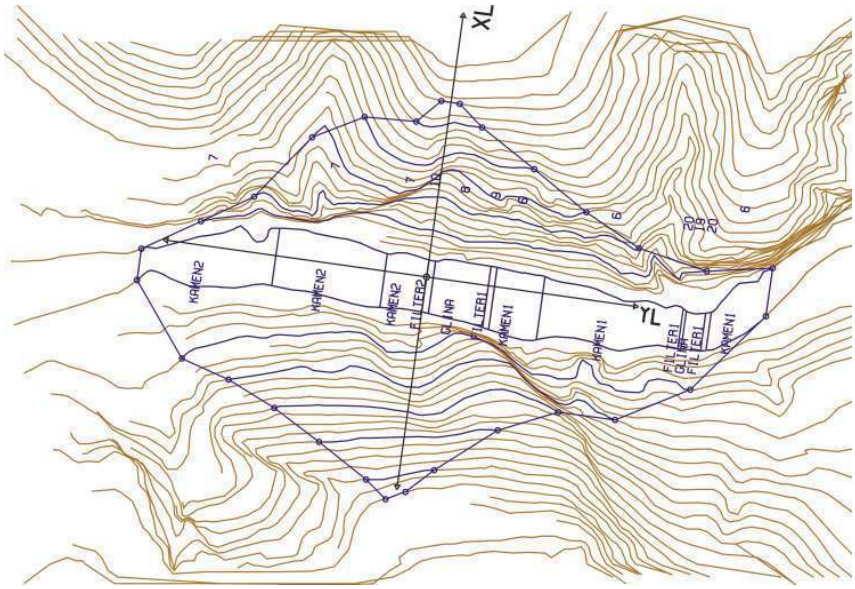


Figure 4 Cumulative presentation of the selected levels used for generation of the model

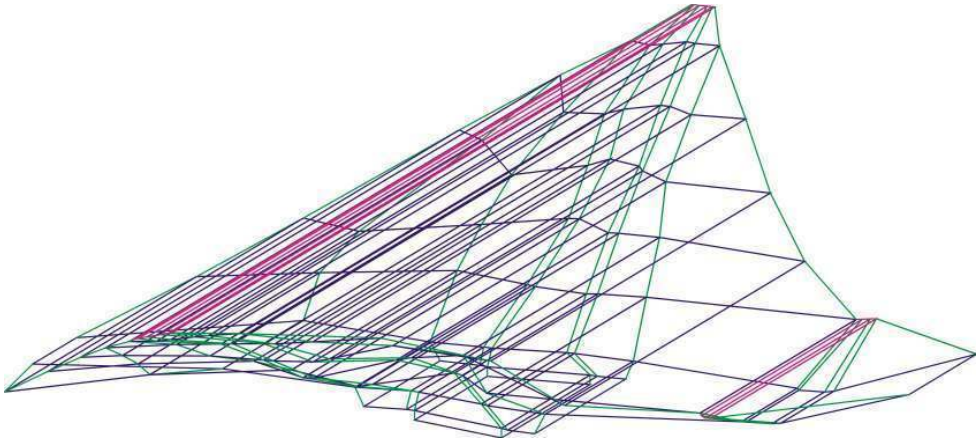


Figure 5 3D Mathematical model of substructures adopted for analysis

2. DYNAMIC RESPONCE OF THE DAM

Used for the performance of the dynamic analysis for determination of the dynamic response of the earth-fill dams were the methods of modal analysis as well as "step by step" direct integration linear acceleration method linear analysis and nonlinear analysis with incorporated constitutive law on nonlinear behavior of soil media at each time step. Compared are the results obtained by these methods.

Within the frames of each finite element, the iterative procedure "Load Transfer Method" is applied, whereat elimination of the vector of excessive stresses, i.e., corresponding residual forces defined in accordance with the Mohr-Coulomb's failure criterion is done iteratively.

The main phases of the "Load Transfer Method" are the following:

- Solved within the frames of each "i"-th time step and each iteration is the incremental differential equation of dynamic equilibrium of the following form:

$$M**\Delta \ddot{U}_i + C**\Delta \dot{U}_i + K**\Delta U_i = \Delta P_i**$$

- Applying the substructure technique, the differential equation of motion refers only to the external points of the mathematical model. Defined in that way are the incremental vectors of displacement, velocity and acceleration at the external points of the system. The dynamic response at the end of each time step is defined by summing up the dynamic response from the beginning of the time step and the effect from the iterations performed in it.

$$U_n = U_0 + \sum_{i=1}^{n} \Delta Ui \qquad n = 1, iter$$

$$\dot{U}_n = \dot{U}_0 + \sum_{i=1}^{n} \Delta \dot{U}i$$

$$\ddot{U}_n = \ddot{U}_0 + \sum_{i=1}^{n} \Delta \ddot{U}i$$

where

iter - number of iterations within the frames of each time step;

$U_0, \dot{U}_0, \ddot{U}_0$ - initial vectors of displacement, velocity and acceleration;

$\Delta U_0, \Delta \dot{U}_0, \Delta \ddot{U}_0$ - incremental values of vectors of displacements, velocity and acceleration.

- Using the incremental displacement vector, defined within each iteration is the vector of incremental strains and the corresponding vector of incremental stresses for each finite element. Herewith, the vector of incremental displacements of each finite element is defined by superposing of part of the vectors of incremental displacements for the external and the internal points of the system. The incremental vector of displacements of the inner points is obtained using the Guyan's transformation. For each finite element, the total

vector of strains and stresses at the end of each iteration is defined as follows:

$$\varepsilon = \varepsilon_0 + \sum_{i=1}^{n} \Delta\varepsilon_i \qquad n = 1, iter$$

$$\sigma = \sigma_0 + \sum_{i=1}^{n} \Delta\sigma_i$$

where

iter - number of iterations within the frames of each time step;

ε_0, σ_0 - initial vectors of strains and stresses;

$\Delta\varepsilon_0, \Delta\sigma_0$ - incremental vectors of strains and stresses.

- At the end of each iteration, the stress state is reviewed for each finite element of the discrete mathematical model. Selected are only those finite elements for which the stress state is in the plasticity zone, i.e., the stress point in the Haigh Westergaard's stress space lies beyond the failure surface in accordance with the Mohr-Coulomb's criterion. Defined for these finite elements are the excessive stresses as a difference between the manifested and the ultimate stresses, which for a given spherical stress tensor and a given stress path, are manifested upon the yielding surface. Determined for such defined excessive stresses are the corresponding residual forces as follows:

$$\{f_{rez}^{e}\} = -\int_V [B]^T \{\Delta\sigma\}_e dv$$

- Solving again the incremental differential equation of dynamic equilibrium only by consideration of the effect of the defined residual forces from the previous iteration, the new vectors of incremental displacements, strains and stresses are obtained in the next iteration.

- Since the residual forces are applied on a system with unchanged stiffness matrix, the excessive stresses exist at each iteration but their intensities are decreased with the increase in the number of iterations, i.e., the iterative process converges. Successive iterations are done until the excessive

stresses and the corresponding residual forces are higher than the tolerance of the iterative procedure.

The damping matrix, in explicit form, according to the Rayleigh's damping concept, is defined as follows:

$$[C] = \alpha[M] + \beta[K]$$

Used to define the (α) and (β) coefficients are two modal dampings $\xi 1$ and $\xi 2$, and their frequencies $\omega 1$ and $\omega 2$, that best present the property of the structure to dissipate energy through the following two equations:

$$\alpha = \frac{2\omega_1\omega_2^2\xi_1 - 2\omega_2\omega_1^2\xi_2}{\omega_2^2 - \omega_1^2} \qquad \beta = \frac{2\omega_2\xi_2 - 2\omega_1\xi_1}{\omega_2^2 - \omega_1^2}$$

For the purpose of defining coefficients (α) and (β) as competent coefficients for the energy dissipation, the first two mode shapes of natural vibrations with frequencies of ω_1=4.48 rad/sec and ω_2=6.28rad/sec and modal dampings of ξ_1=10% and ξ_2=15% of the critical have been adopted.

Dynamic analysis has been performed for the effect of harmonic excitation with frequency of ω_o=5.2 rad/sec, peak acceleration A_o=0.3g and time duration of T=20sec. The harmonic excitation has been applied only in the direction of the global X-axis of the system. The time step of direct integration is Δt=0.02 sec.

Such a selected harmonic excitation whose frequency is close to the first fundamental mode of natural vibrations of the system has a large, i.e., dominant dynamic factor of participation in the system response. From the same reasons, the dynamic factor of participation of the remaining frequencies shall be lower, which is confirmed by the fact that the responses obtained by the modal analysis in which only the first mode of the system is included and the response obtained by direct integration method (linear analysis), point to good correlation, particularly referring the response in the global X-axis. Unlike these, the dynamic response obtained by means of the Mohr-Coulomb's criterion for nonlinear behaviour of soil media gives another picture of the stress-strain state of the dam body.

Figure 6 shows the mode shapes of natural vibrations only for the clayey core.

The dynamic response of relative displacements is presented through individual finite elements at selected cross-sections as follows: cross-section Y=266m immediately next to the right support and cross-section Y=150m representing the central part of the dam.

Figures 8 and 9 present the time histories of the developed response of relative displacements as well as histories of developed plastic deformations in

the three main directions i.e., the global X, Y and Z axes, for the chosen finite elements in the selected sections. For the same elements, figures 10 and 11 present the time histories of relative velocities and absolute accelerations developed only in the global X direction that is direction of applied dynamic force.

The time histories of relative displacements point out that the system is out of the transient state of vibration and enters into the steady state after the first two to three periods of the system's response. Such a fast transition from a "transient" into "steady state" vibration state results from the small difference between the frequencies of the exciting force and the frequency of the first fundamental mode of natural vibrations of the system, which in this case, has a dominant effect on the response as well as on the adopted modal damping by which is defined the Rayleigh's damping matrix. At the cross-section Y=150m representing the central part of the dam characterized by a greater flexibility, the transition from the "transient" into the "steady state" vibration state is faster compared to cross-sections Y=266m which is situated in the vicinity of the support.

The difference in the relative displacements between the linear and nonlinear analysis (direct integration) for cross-section Y=266m, immediately next to the right support, in a finite element of the contact between the water prism and the filtering layer, is 35% - 40%. The maximum moment plastic deformations are Up,x=0.0205m in X direction, Up,y=-0.034m in Y direction, and Up,z=0.028m in Z direction. The element tends to undergo plastic deformation in X direction, i.e., in the direction of excitation action, with a tendency for vertical displacement (settlement), figure 8.

Comparing the displacement response obtained by modal analysis and direct integration (linear analysis), deviation in all three directions, particularly the global Y and Z directions is evident at this cross-section. The reason is that the dynamic force acts in the global X direction so that the factor of participation of the included mode shapes in the modal analysis for the remaining two directions is inadequate.

The difference between the relative displacements obtained by linear and nonlinear analysis (direct integration) for cross-section Y=150m, the central part of the dam, in a finite element close to the crest, amounts to 20% in X direction and 43-56% in Z and Y direction, respectively. The maximal moment plastic deformations amount to Up,x=-0.28m in X direction, Up,y=0.098m in Y direction and Up,z=-0.12m in Z direction. The element has the tendency to be plastically deformed in the direction of excitation action, with a tendency of vertical displacement (settlement), figure 9.

Comparing the displacement response obtained by modal analysis and direct integration (linear analysis) at this cross-section, it can be noticed that there is a very good agreement of the displacement in the global X direction. The central part of the dam as the most flexible part of the structure has the most intensive dynamic response under harmonic excitation, whereat the first fundamental mode of natural vibrations of the system has a dominant effect upon the response in the global X direction.

According to the nonlinear analysis, the dynamic amplification factor of the dynamic effect at the cross-section Y=266m for the finite element of the contact between the water prism and the filtering layer is DAF=1.08, figure 10, while for the finite element at the dam crest it is DAF=1.36 (it is not presented).

According to the nonlinear analysis, the dynamic amplification factor of the dynamic effect at the cross-section Y=150m at the dam crest is DAF =4, figure 11, while at 2/3 of the core height, it is DAF=2.4, (it is not presented) The dynamic amplification factor of the dynamic effect obtained through nonlinear analysis is smaller than that obtained by the linear analysis.

The residual plastic deformations in the dam body are obtained by superposing the vector of residual displacements in the course of the iterative processes within the frames of all the time steps, i.e., the plastic deformation at each point of the model is obtained by integration of the curve of the time history of plastic deformations for that point.

Figure 12, shows the residual plastic deformations only for the clayey core. It can be concluded that after the effect of the harmonic excitation, the clayey core shall be buckled along the dam crest, with maximum plastic deformation in X direction Upx,max=-0.44 m and maximum plastic deformation in Z direction Upz,max=-0.29m. The residual plastic deformation in Y direction, in the upper third of the core shows the tendency of being compressed toward the central part Upy,max=-0.16m. Figs 13 and 14 show the plastic deformations at individual cross-sections of the dam. With its upper part, the longitudinal section xl=0m passes through the clayey core. The residual plastic deformation of these cross-sections confirms the statement of flexibility of the upper third of the core. Based on the residual plastic deformations, it can be concluded that there is compaction in Z direction, i.e., settlement of the dam as a result of its nonlinear dynamic response.

Figure 15 shows the time histories of the principal and component stresses for a finite element in the clayey core located at 2/3 of its height, near the filter on the upstream side of the dam, and at cross-section Y=150m, central part of the dam. Comparison has been made between the stresses obtained from the linear analysis by using the direct integration method and those obtained in the nonlinear analysis performed in accordance with the Mohr-Coulomb's criterion on nonlinear behaviour of soil media.

Due to the linear analysis, the principal stress σ_1 is a tensile stress, which according to the Mohr-Coulomb's failure criterion, cannot be sustained by the clay. The stress state, according to the nonlinear analysis, is transferred into the zone of pure compression. It is evident that there is a reduction of component shear stresses down to the level of the allowable ones which are in function of the manifested spherical tensor of stresses and the stress path.

The time histories of principal and component stresses that refer to finite elements located at the base show that the bottom of the dam is under compression, with high intensities of spherical compressive stresses and weakly expressed nonlinearity, (not presented).

Displayed in figures 16 and 17 are the stress-shear strains relationships τ_{xy}-ε_{xy}, τ_{xz} -ε_{xz} and τ_{yz}-ε_{yz} in chosen finite elements and at different cross-sections of the dam. The shear strains are of the order of 10-3. The stress-shear strain diagrams clearly illustrate the nonlinear elasto-plastic behaviour of the soil media in accordance with the adopted constitutive law on nonlinearity. The stresses and the shear strains are with lower intensity toward the supports and in the higher layers of the dam compared to those in the lower layers. They are the greatest in the central part of the dam.

Presented in figures 18 and 19 are snapshots of the moment deformation state of the chosen sections of the dam, obtained through nonlinear analysis. Each snapshot represents the time moment of manifestation of the widest zone of occurrence of cracks as a result of exceedence of the allowable tensile stresses. Indicated by different colours are the zones of occurrence of cracks and the range of the manifested tensile strains.

In the course of the dynamic response of the dam, the development of tensile strains (increase and decrease) is monitored and hence knowledge is acquired about the process of opening and closing of the manifested cracks.

Prepared is a programme for visualization of the dynamic response of the integral dam and per required cross- and longitudinal sections by designation of the zones of occurrence of cracks due to exceedence of the allowable tensile stresses, in accordance with the Mohr-Coulomb's failure criterion combined with the tension cutoff principle.

In the practice of treating the materials incorporated in the dam body as linearly elastic, the application of the concept of "mobilized strength" has so far served for definition of the stability of earth-fill dams. Knowing the stress tensor within the frames of each finite element, defined are the octahedral planes of maximum shear stresses in which the value of normal stress is the octahedral stress, i.e., the spherical stress. The ultimate shear stress is defined according to the Mohr-Coulomb's criterion using the equation $\tau_{ult} = C + \sigma_{oct} tg\varphi$. The mobilized strength is obtained as a relationship between the maximum manifested shear stress and the ultimate shear stress $MJ = abs(\tau_{\max} / \tau_{ult})$. In the case when the mobilized strength for some finite element is higher than a unity, there is a tendency for activation of the medium within the frames of that finite element, i.e., its motion in the direction of the octahedral plane.

However, in the case when nonlinear analysis is applied, according to the Mohr-Coulomb's criterion, the manifested maximum shear strength of the finite elements that are in the plasticity zone is reduced down to the level of the ultimate shear stress, so that the mobilized strength acquires a unit value. It can be concluded that the mobilized strength in the case of linear analysis shall have a value lower or equal to unity. In the case when the element is in the zone of plastic behavior and the stress point lies on the yielding surface, the mobilized strength is equal to 1. So, in the case of nonlinear analysis, the mobilized strength gives an information about the character of the stress state of the finite elements. The stability of the finite elements that have exerted a plastic behavior should be judged on the basis of the manifested plastic deformations in the domain of such finite elements.

In earth-fill dams, the potential shear surfaces are most frequently in the shape of a shell, figure 20. The curved shear surface in the form of a shell is defined by means of a parabola system. Definition of the shape of the shells and their placement in certain parts of the dam is done automatically.

The curved surface which is mathematically described by a parabola system is approximated by a system of a certain number of small triangles (planes). Defined for each triangular surface is the direction of the normal and the intersection with the finite elements, i.e., it is expressed as a sum of elementary intersected areas which constitute the triangular surface when

assembled. On each elementary intersection area there acts the stress tensor of the finite element in whose domain that surface stretches. The stress tensor is projected along the normal and the tangent of the elementary intersection surface and integrating the normal and tangential stresses in the domain of the curved surface, the coefficient of safety against sliding is defined.

The time histories of the safety coefficient against sliding have been defined on the basis of two performed analyses - linear and nonlinear analysis. The time histories start with the value of safety coefficient against sliding defined in static conditions and at time t=0 sec. It can be concluded that the safety coefficient against sliding defined on the basis of the linear analysis is lower than that obtained through the nonlinear analysis, figure 21. This is due to the reduction of the active shear forces down to the level of the ultimate ones, in conditions of existence of ultimate plastic equilibrium.

At reaching the state of ultimate plastic equilibrium, the active shear forces are under control at the expense of which are developed additional plastic deformations whose intensities are competent for the evaluation of the stability of the integral dam.

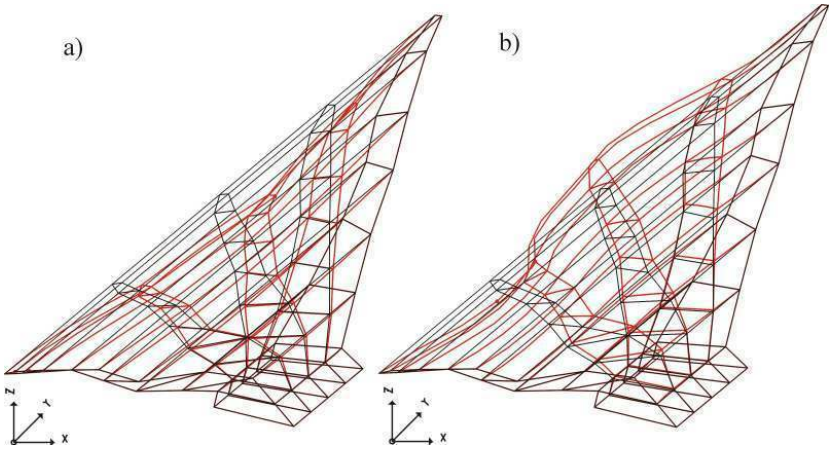


Figure 6 a) First mode shape T=1.4 sec b) Second mode shape T=1.0 sec

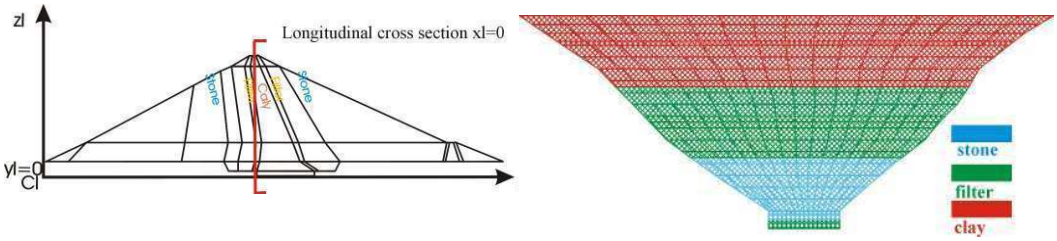


Figure 7 Position and material identification in longitudinal section xl=0

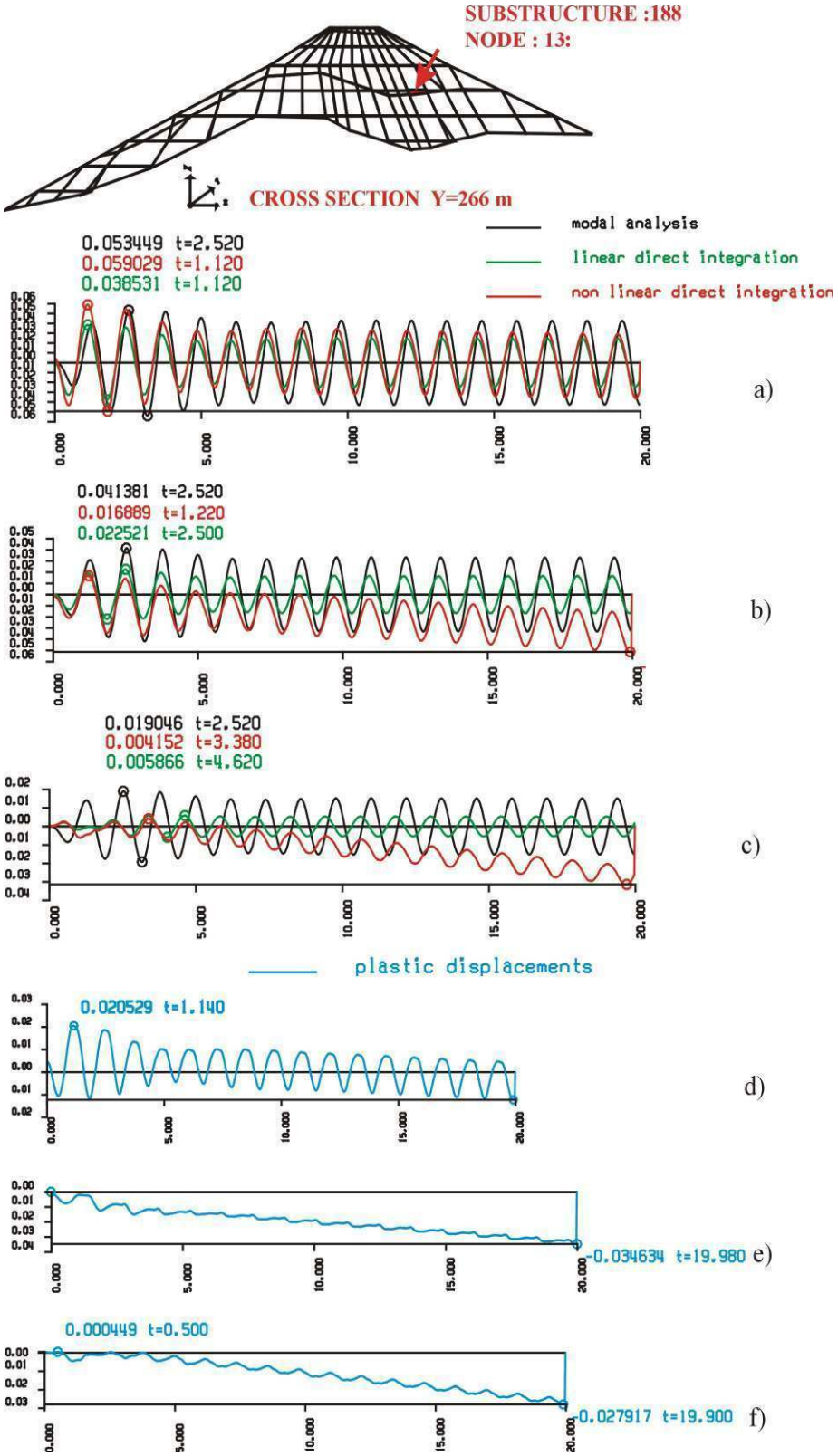


Figure 8 Time histories of relative displacement of the chosen finite element in section Y=266m; a) X-direction b) Y-direction c) Z-direction and time histories of plastic deformations in d) X-direction e) Y-direction f) Z-direction

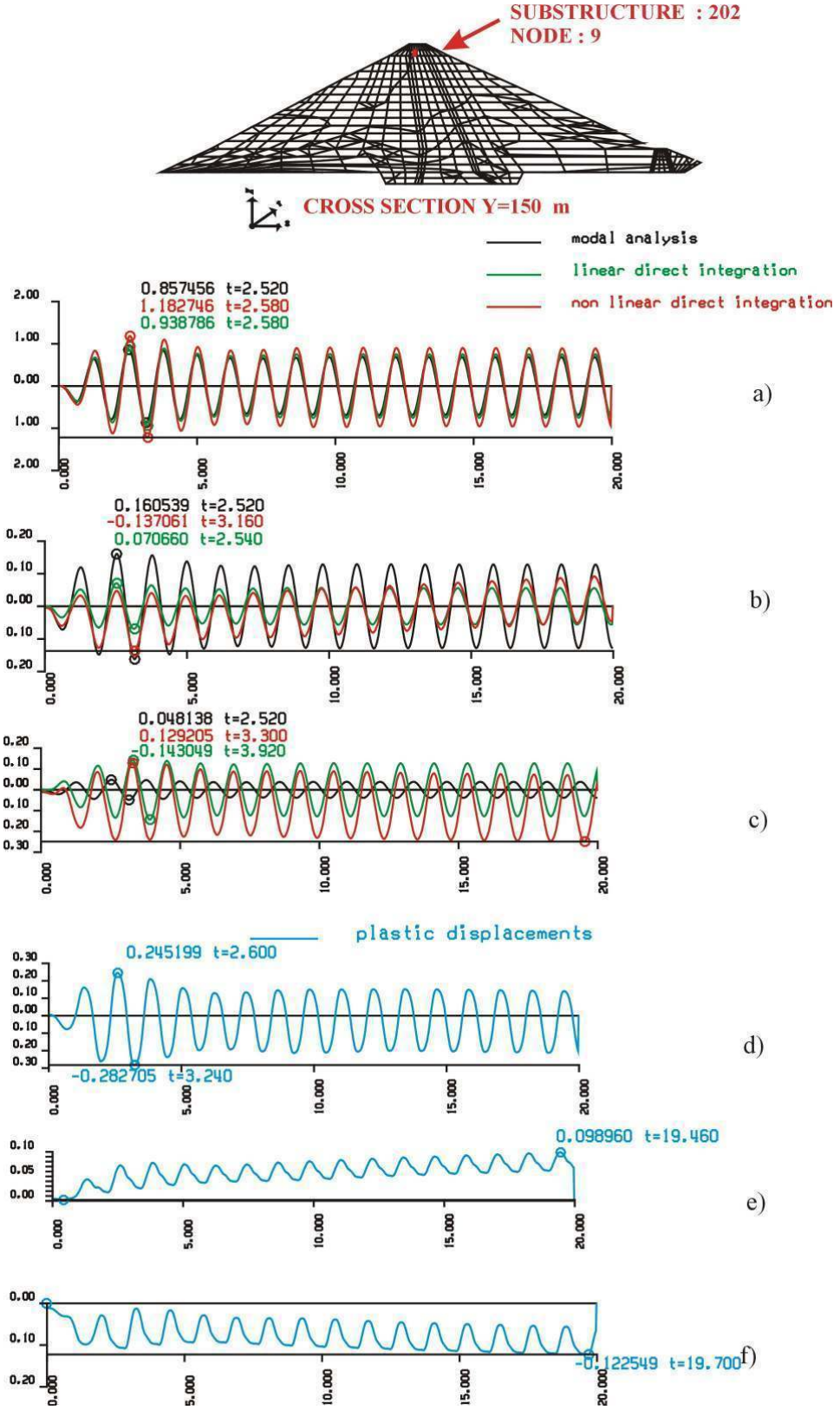


Figure 9 Time histories of relative displacement of the chosen finite element in section Y=150m X-direction b)Y-direction c) Z-direction and time histories of plastic deformations in d) X-direction e) Y-direction f) Z-direction

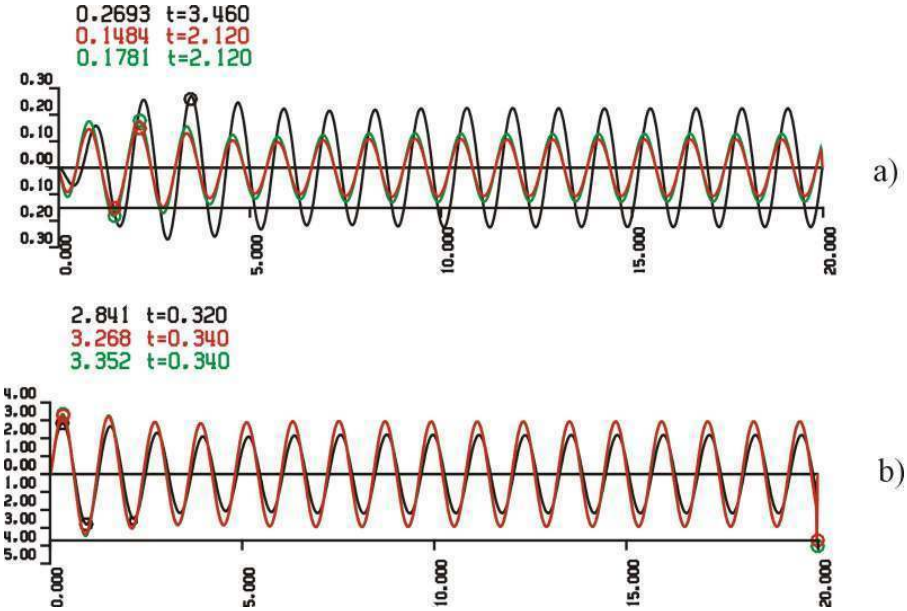


Figure 10 Time histories of a) relative velocities (m/sec) and b) absolute accelerations (m/sec2) for the chosen finite element in section Y=266m

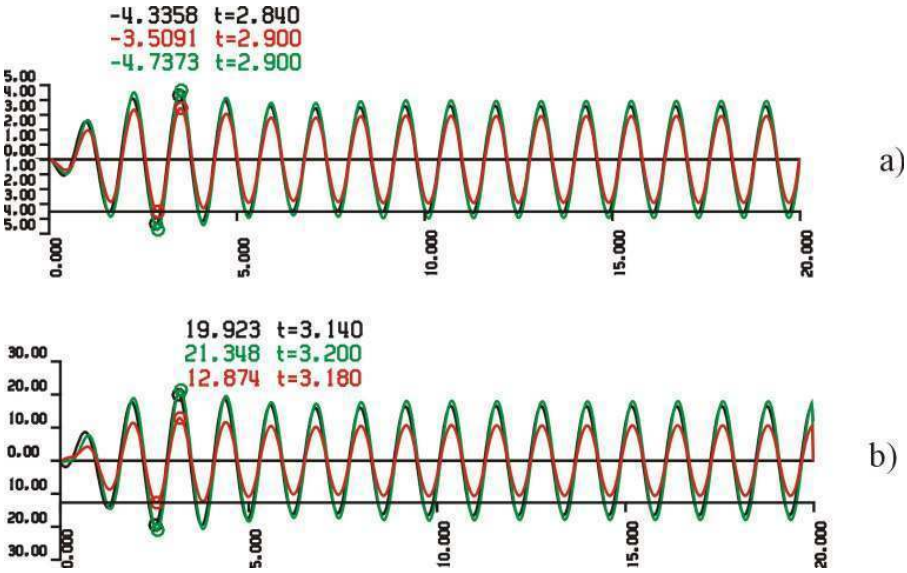


Figure 11 Time histories of a) relative velocities (m/sec) and b) absolute accelerations (m/sec2) for the chosen finite element in section Y=150m

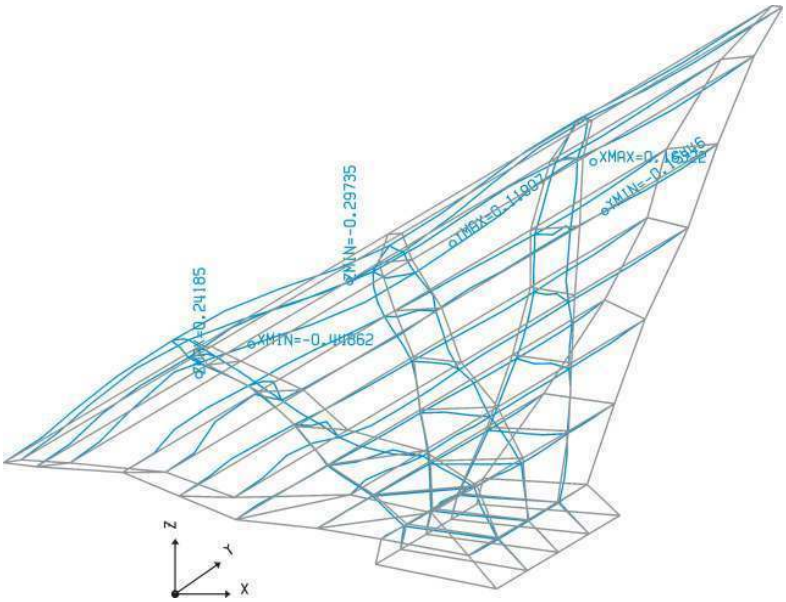


Figure 12 Plastic deformations of the clayey core

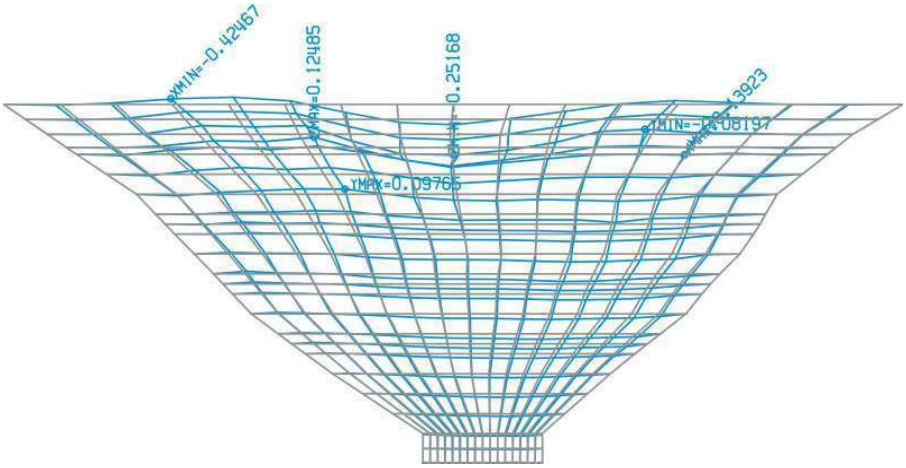


Figure 13 Plastic deformations in longitudinal section xl=0

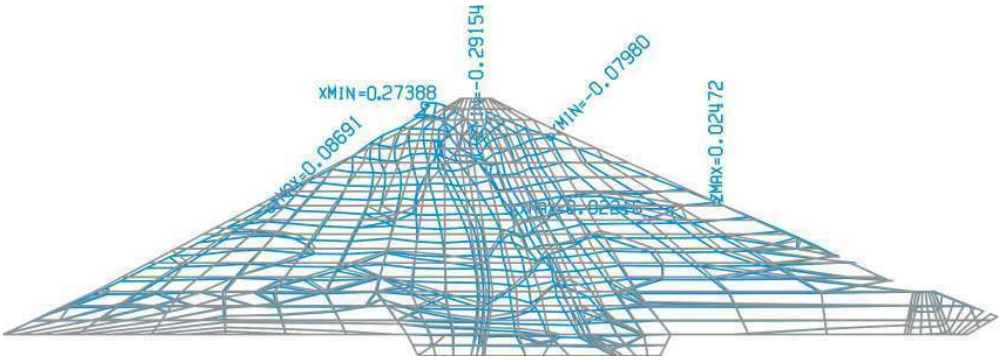
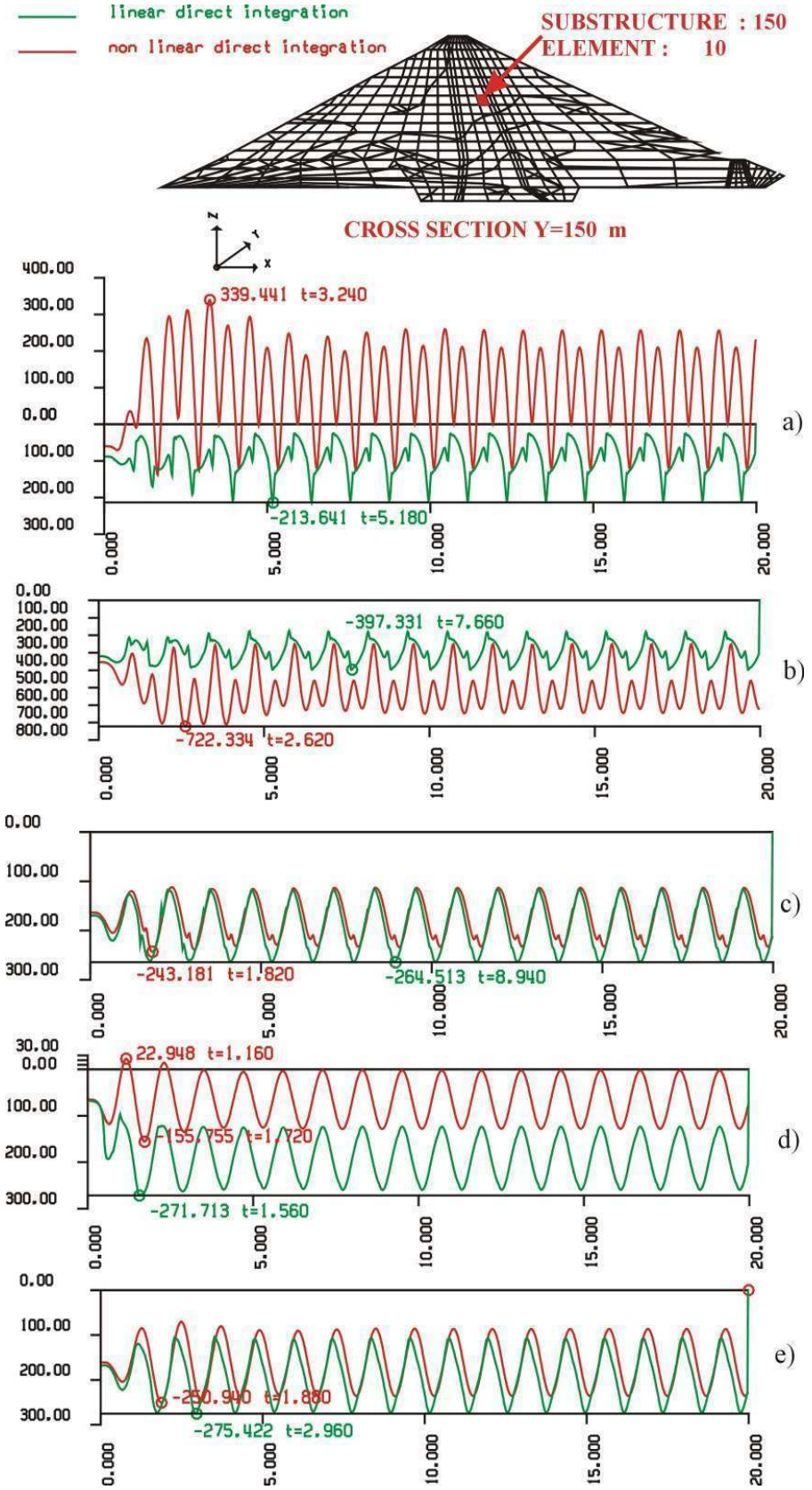


Figure 14 Plastic deformations in the central cross section Y=150m


linear direct integration
non linear direct integration
SUBSTRUCTURE : 150
ELEMENT : 10
CROSS SECTION Y=150 m
339.441 t=3.240
-213.641 t=5.180
a)
-397.331 t=7.660
-722.334 t=2.620
b)
-243.181 t=1.820
-264.513 t=8.940
c)
22.948 t=1.160
-155.755 t=1.720
-271.713 t=1.560
d)
-250.940 t=1.880
-275.422 t=2.960
e)

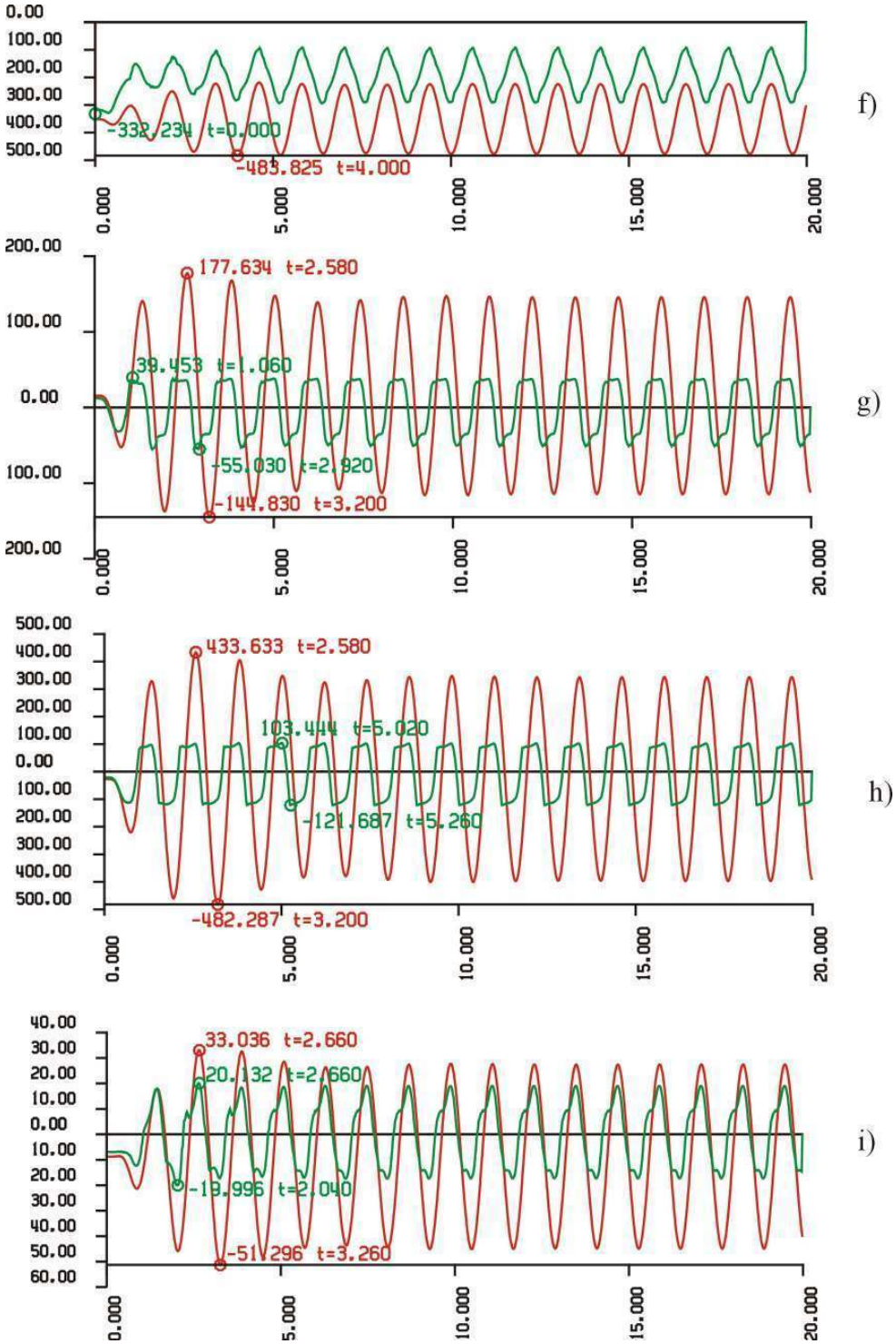


Figure 15 Time histories of stresses [kN/m^2] for selected finite element a) Principal stress σ_1 b) Principal stress σ_2 c) Principal stress σ_3 d) Component stress σ_x e) Component stress σ_y f) Component stress σ_z g) Component stress σ_{xy} h) Component stress σ_{xz} i) Component stress σ_{yz}

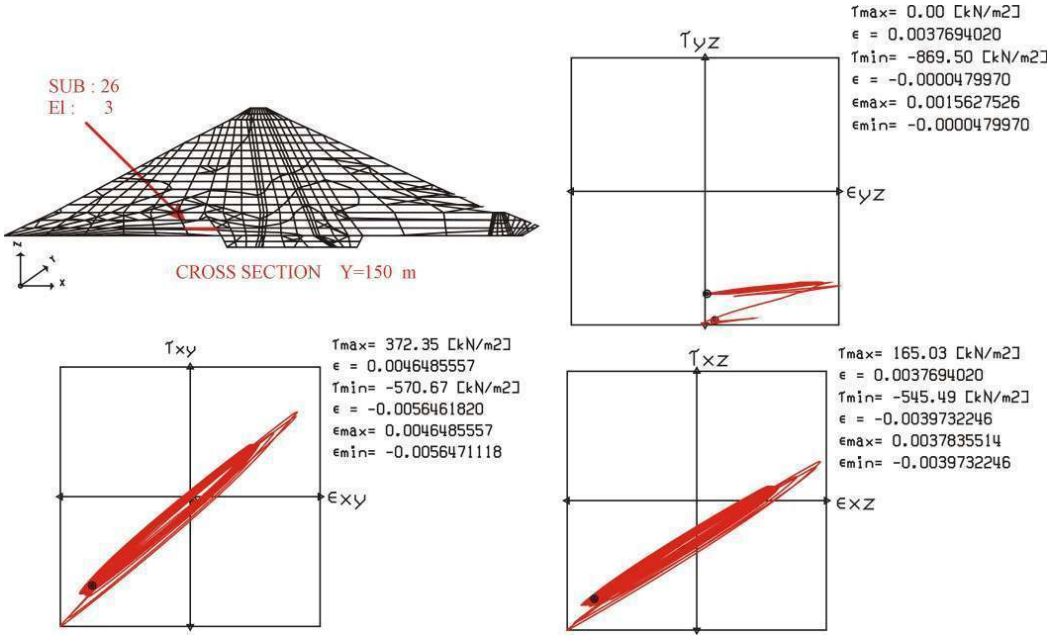


Figure 16 Constitutive relationship between shear stresses and strains for the chosen finite element

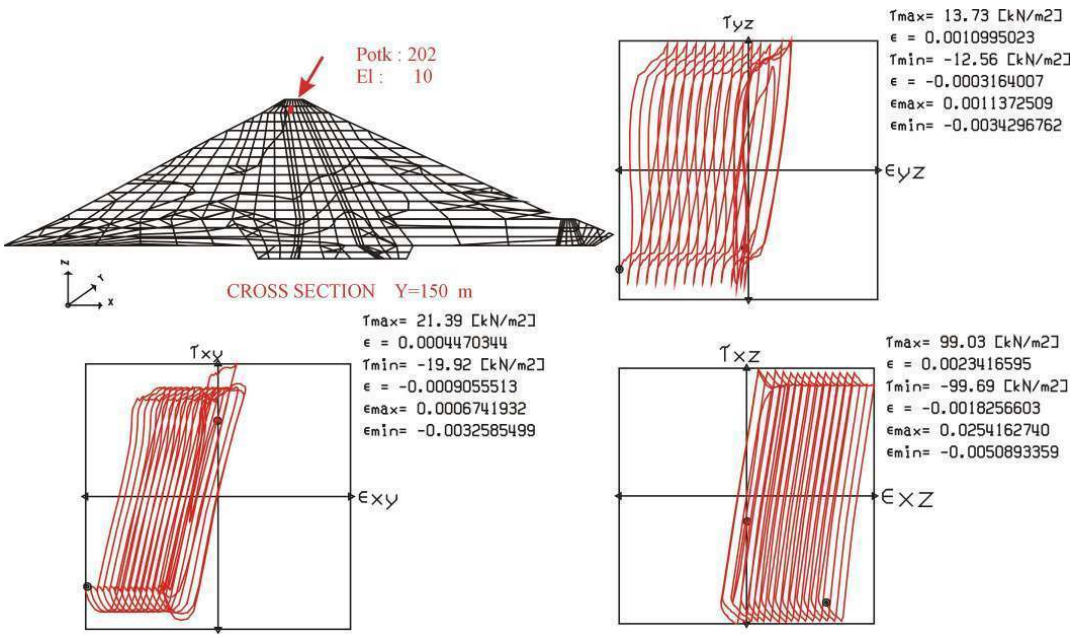


Figure 17 Constitutive relationship between the shear stresses and strains for the chosen finite element

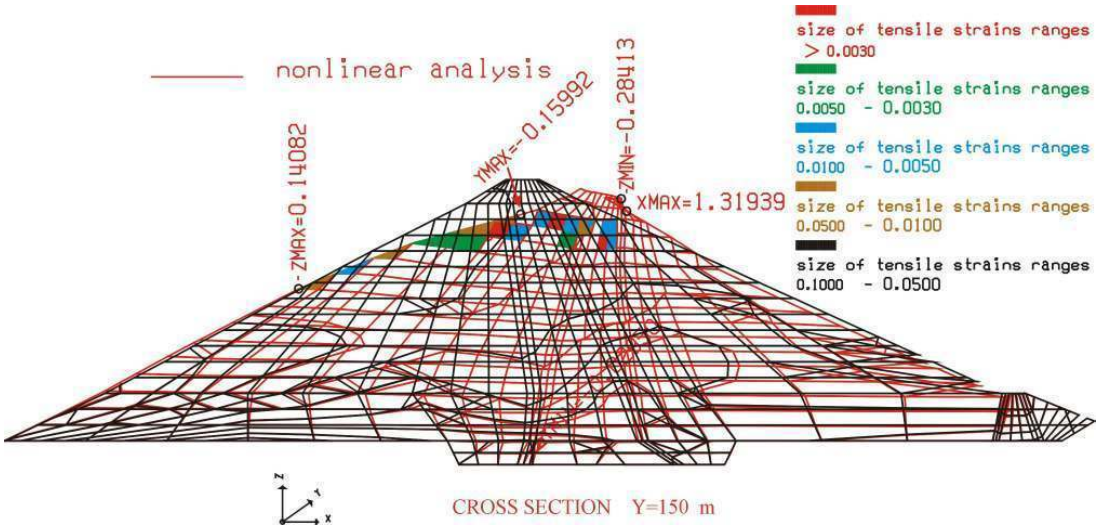


Figure 18 Snapshot of deformations due to non-linear analysis in time T=2.58 sec when the extreme cracking zone occurred in the considered section

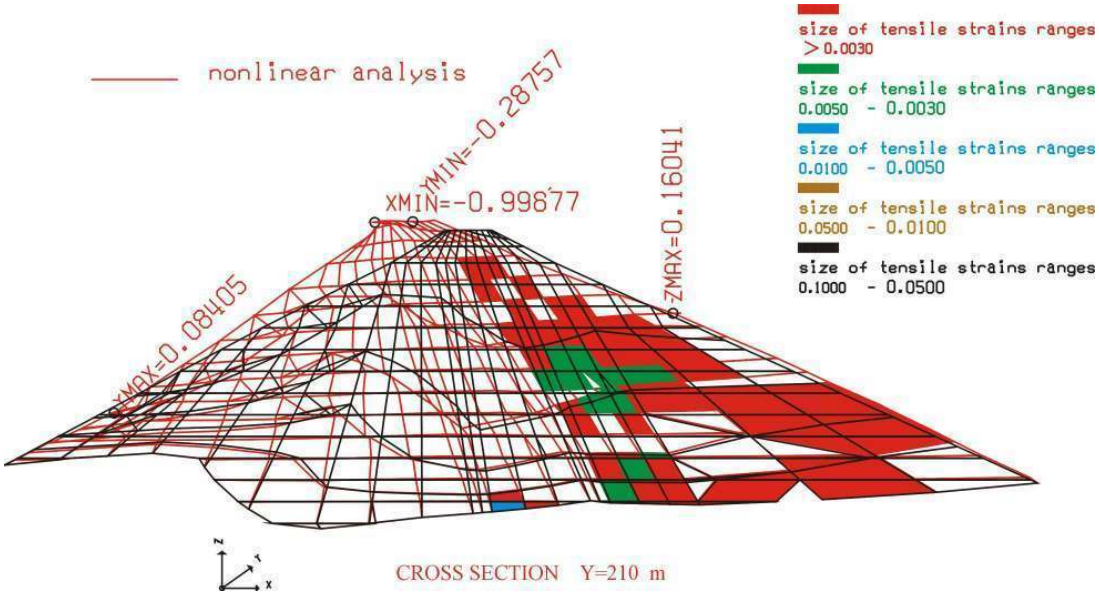


Figure 19 Figure 19 Snapshot of deformations due to non-linear analysis in time T=3.26 sec when the extreme cracking zone occurred in the considered section

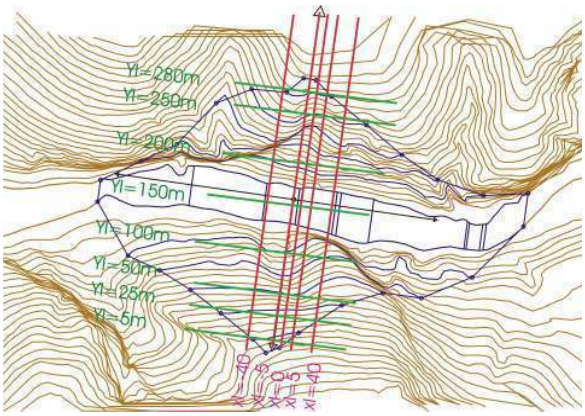


Figure 20 Position of the sections on plane

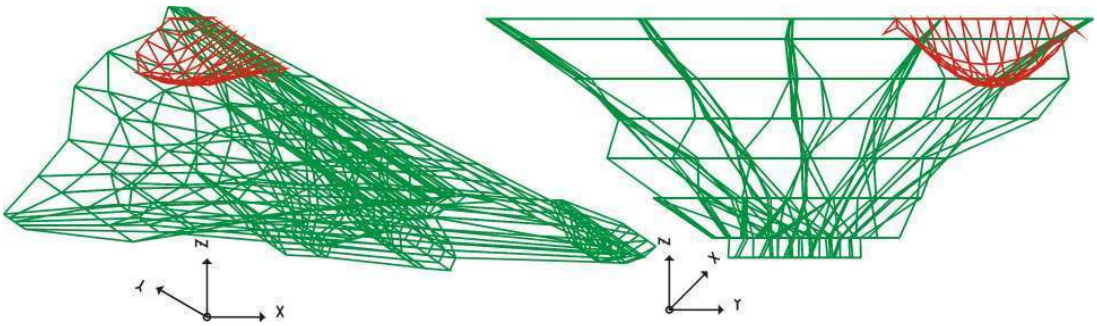


Figure 21 Position of the potential sliding surface (shell) in the dam

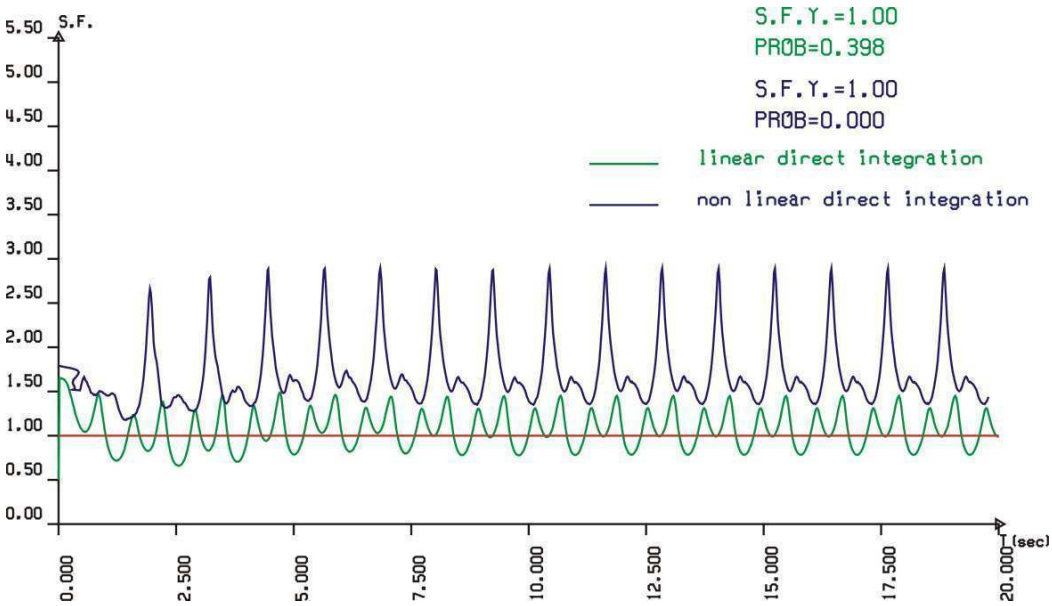


Figure 22 Time history of safety coefficient against sliding

3. CONCLUSION

The dam is situated in a "V"-shaped canyon . Such a geometrical shape of the canyon and the structure has a dominant effect upon the stress-strain state whereby the application of a 3D mathematical model is necessary.

From the time histories of relative displacements, it can be concluded that, after the first two to three response period, the system is out of the transient state of vibration and enters into a steady state state. Such a fast transition from a transient into a steady state state of vibration is a result of the small difference in the frequencies of the excitation force and the frequency of the first fundamental mode of natural vibrations of the system, which in this case has a dominant influence on the response as well as on the adopted modal damping by which is defined the Reyleigh damping matrix.

In the cross-sections Y =150 m that present the central part of the dam characterized by a greater flexibility, the transition from the transient state into steady state of vibration is faster compared to the cross-sections Y =266 m, which are in the vicinity of the support.

The difference in the relative displacements between the linear and nonlinear analysis (direct integration) for X direction is 20%, whereas for the other two directions, this percentage is higher as a result of higher plastification effect.

The maximal value of the dynamic factor of amplification of the dynamic effect according to the nonlinear analysis is in the central part of the dam crest and it is DAF=4, whereat it is smaller than the corresponding dynamic amplification factor obtained via the linear analysis. The dynamic amplification factor decreases toward the supports and along depth.

In dynamic conditions, the clayey core suffers plastic buckling deformations, which are particularly pronounced in the upper third of the core. The reason for such a deformation of the core are its small dimensions (slender flexible core), particularly in the upper third of the dam. Maximum plastic deformation in X direction Upx,max = -0.44 m and maximum plastic deformation in Z direction $U_{pz,max}$ = -0.29 m.

Based on the residual plastic deformations, it may be concluded that settlement of the dam takes place as a result of the nonlinear dynamic response.

The componental shear stresses τ_{xy} ,τ_{yz} and τ_{xz} obtained through nonlinear analysis are reduced in respect to those obtained by linear analysis. The reduction is down to the level of allowable octahedral shear stresses in function of the existing spherical stress tensor.

The stress state in the deep zones of the dam is in the range of pure pressure, with greater intensity of spherical stresses, which results in a slightly expressed nonlinearity.

The shear strains are of the order of 10-3. The stress-shear strain diagrams clearly illustrate the nonlinear elastic-plastic behaviour of soil media in accordance with the adopted constitutive law of nonlinearity.

In the course of dynamic response of the dam, the development of tensile strains is monitored which enables acquiring of knowledge on the process of opening and closing of the manifested cracks.

The time of occurrence of cracks in the time histories of stresses are recognizable by the fact that, in all the time histories of principal stresses at the same time, the stresses obtain the value of σ=0, i.e., the stresses curves tangent the abscissa that represents the time axis.

The mobilized strength in the case of nonlinear analysis has a value less or equal to unity $MJ = abs(\tau_{\max} / \tau_{ult}) \leq 1$. In the case when the element is in the zone of elastic behaviour, the stress point is below the yielding surface and the mobilized strength is less than a unit. In the case when the element is in the zone of plastic behaviour, the stress point lies on the yielding surface and the mobilized strength is close or equal to unity. In a nonlinear analysis, the mobilized strength provides an information about which finite elements are in the state of ultimate plastic equilibrium.

For those finite elements in which plastic behaviour takes place, judgement should be made based on the manifested plastic deformations in the domain of such finite elements.

The safety coefficient against sliding defined on the basis of nonlinear analysis is lower than that obtained via linear analysis. This is due to reduction of the active shear forces down to the level of the ultimate ones, in conditions of existence of ultimate plastic equilibrium.

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PRESOJA VPLIVOV NA OKOLJE ZA ČRPALNO HIDROELEKTRARNO AVČE

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POVZETEK

V članku so predstavljeni rezultati presoje vplivov na okolje za črpalno hidroelektrarno (ČHE) Avče. Cilj izdelave poročila o vplivih na okolje je bilo ovrednotenje potencialnih negativnih ali pozitivnih vplivov na sestavine posameznih okolij v vplivnem območju ČHE Avče, ki so sestavine naravnega okolja ter sestavine kulturnega in družbenega okolja. Za vsak element smo opravili presojo vplivov na okolje v času gradnje in v času obratovanja, za primer brez upoštevanja omilitvenih ukrepov in za primer z upoštevanjem omilitvenih ukrepov. Na podlagi rezultatov presoje vplivov na okolje smo ocenili, da je izgradnja ČHE Avče v okviru predvidenih ukrepov in priporočil z vidika varovanja okolja sprejemljiv poseg za okolje. Za zmanjšanje negativnih vplivov na okolje smo podali rešitve in ukrepe za varovanje okolja, ohranjanja narave, varstva kulturne dediščine ter trajnostne rabe naravnih dobrin. Namen monitoringa je identifikacija, spremljanje in ugotovitev trendov pojavov nastalih kot posledica gradnje in obratovanja ČHE Avče. Rezultati monitoringa bodo služili za določitev gradbenega in obratovalnega režima ČHE Avče ter nujnih ukrepov za preprečitev pojavov nevarnih in škodljivih za okolje.

SUMMARY

The article presents the results of environmental impact assessment for the pumped storage hydropower plant (PSHPP) Avče. The objective of preparing the environmental impacts report was to evaluate potential negative or positive effects on individual environmental components within the influence area of the PSHPP Avče, covering the elements of natural environment as well as the elements of cultural and social environments. The environmental impact assessment was performed for every element during the time of construction and during the operating period, with and without taking into account the mitigation measures. It was estimated on the basis of the environmental impact assessment that the construction of the PSHPP Avče was an environmentally acceptable action. Solutions and measures were proposed for the reduction of negative environmental impacts in order to protect the environment, preserve the nature, protect the cultural heritage and to ensure the sustainable use of natural goods. The purpose of monitoring was to identify, control and determine the trends in phenomena resulting from the construction and operation of the PSHPP Avče. The monitoring results will serve to determine the construction and operating regimes for the PSHPP Avče and the emergency measures for the prevention of environmentally dangerous and harmful events.

1. UVOD

Poročilo o vplivih na okolje za črpalno hidroelektrarno Avče je izdelal Limnos d.o.o. v sodelovanju s podizvajalci v letu 2004. Pravna osnova za izdelavo Poročila o vplivih na okolje je bila dana v Zakonu o varstvu okolja (Ur. l. RS, št. 41/04) in v Zakonu o graditvi objektov (Ur. l. RS št. 110/02). Poročilo o vplivih na okolje za Črpalno hidroelektrarno Avče je bilo izdelano v skladu z Uredbo o vrstah posegov v okolje, za katere je obvezna presoja vplivov na okolje (Ur. l. RS, št. 66/96 in 12/00) in Navodilom o metodologiji za izdelavo poročila o vplivih na okolje (Ur. l. RS, št. 70/96).

Cilj izdelave poročila o vplivih je bilo ovrednotenje potencialnih negativnih ali pozitivnih vplivov na sestavine posameznih okolij v vplivnem območju ČHE Avče, ki so sestavine naravnega okolja ter sestavine kulturnega in družbenega okolja.

Obratovanje načrtovane črpalne hidroelektrarne (ČHE) Avče je predvideno v tedenskem izravnalnem režimu, v katerem bo elektrarna izkoriščala koristno vsebino zgornjega načrtovanega akumulacijskega bazena velikosti 2,173,000 m3 med nivojema 597 in 625 m n.m., dnevno pa tudi koristno vsebino spodnjega akumulacijskega bazena Ajba na reki Soči, kjer je na voljo ca 416.000 m3 vode med nivojema 104.50 in 106 m n.m.

Črpanje vode iz akumulacije Ajba bo predvidoma med tednom med 24 in 6 h zjutraj t.j. v času nizke tarife električne energije, medtem ko bo obratovanje elektrarne prilagojeno dnevnemu konzumu potrošnje električne energije.

2. ZNAČILNOSTI LOKACIJE

Območje izgradnje in obratovanja ČHE Avče bo vplivalo na štiri različna okolja:

1. Okolje zgornje akumulacije je Banjška planota oziroma njen zahodni rob. Na celotni planoti in tudi v okolici Kanalskega Vrha je prepletanje plitvih do zmerno globokih kraških kotanj nepravilnih oblik ter vmesnih kopastih vrhov ali kratkih kopastih slemen. Na območju predlagane akumulacije so peščenjaki in laporji krednega fliša z vložki apnenčevih breč, ki so omogočili pojave zakrasevanja. Območje akumulacije je krajša dolina ali podolgovata depresija z blagimi pobočji, ki so v kmetijski rabi. Na dosedanjih kmetijskih površinah so slabo obdelane oziroma opuščene njive, ostanki ekstenzivnih sadovnjakov in košena travišča.

Prevladujoče traviščne združbe so:

- Arrhenatheretum elatioris;
- Bromo-Danthonietum calycinae;
- Bromo-Plantaginetum mediae.

Na državni ravni je območje Kanalskega Vrha varovano kot I. območje kmetijskih zemljišč, območje je sestavni del predlaganega regijskega parka Trnovsko-Nanoška planota. Na območju predvidenega akumulacijskega bazena ni površinskih vodotokov. Skoraj celotno območje predvidenega bazena je bodisi v II. in III. predvidenem vodovarstvenem pasu zajetja Ajbice (vodovod Bodrež), bodisi v III. obstoječem vodovarstvenem pasu zajetja Mrzlek.

2. Cevovod bo potekal po pobočju nad dolino Soče pod Avškim vrhom. Banjška planota se na tem mestu proti zahodu strmo spušča v dolino reke Soče med Bodrežem in Kanalom, proti severu pa v dolino Sočinega pritoka Avščka nad krajem Avče. Cevovod bo povezoval spodnjo vodno akumulacijo Ajba, zgornjo akumulacijo črpalne hidroelektrarne in njeno strojnico. V podlagi se menjujejo flišni laporji s tankimi polami kremenovih peščenjakov, vmes pa nastopajo večje debeline apnenčevih breč in apnenčevih peščenjakov. Apnenčevi peščenjaki in apnenčeve breče so močno zakraseli. V strmem delu pobočja se kažejo erozijski pojavi - manjši zemeljski plazovi. Zaradi mehkih karbonatov, ki so tu geološka podlaga, je na bolj strmih pobočjih pričakovana erozija. Pobočja so večinoma poraščena z gozdom.

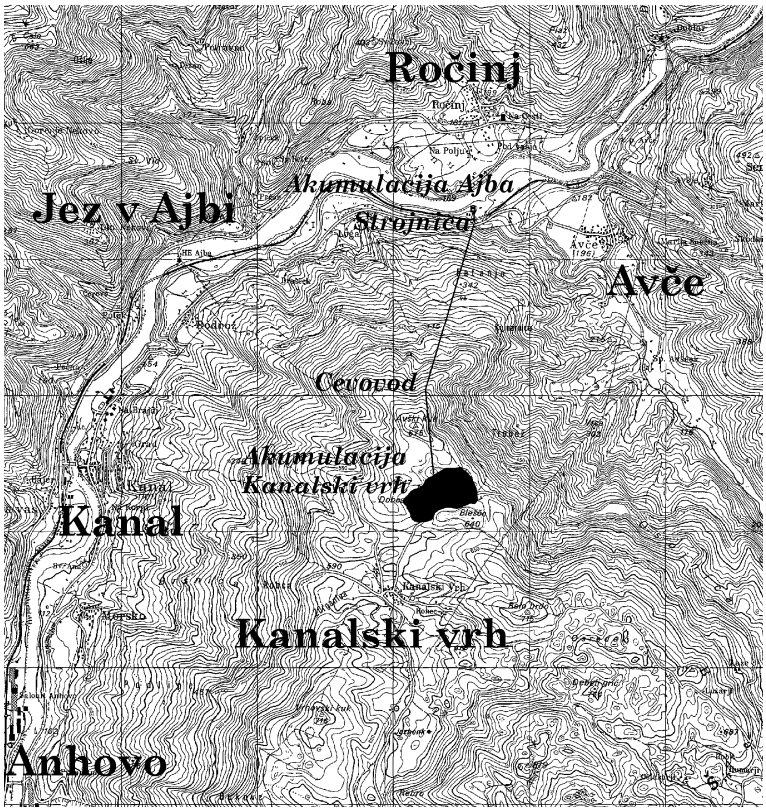
Prevladujoča gozdna vegetacija na pobočjih so listnati, večinoma bukovi, gabrovi, gradnovi in jesenovi gozdovi, zlasti iz združb:

- Castaneo sativae-Fagetum (gozd bukve in pravega kostanja);
- Castaneo-Fagetum sylvaticae var. geogr. Ruscus aculeatus (gozd bukve in pravega kostanja z bodečo lobodiko)
- Cytisantho-Ostryetum.
- Hacquetio-Fagetum var. geogr. Sesleria autumnalis;
- Lamio orvalae-Fagetum (gozd bukve in velike mrtve koprive);
- Ornithogalo pyrenaici-Carpinetum betuli (gozd navadnega gabra in pirenejskega ptičjega mleka);
- Ornithogalo pyrenaici-Carpinetum betuli (submediteranski gozd belega gabra);
- Ornithogalo pyrenaici-Fagetum (gozd bukve in pirenejskega ptičjega mleka);
- Ostryo carpinifoliae-Fraxinetum orni (gozd malega jesena in črnega gabra);
- Ostryo-Fagetum var. geogr. Luzula nivea;
- Seslerio autumnalis-Fagetum (gozd bukve in jesenske vilovine = submediteranski bukov gozd);

3. Strojnica bo zgrajena na bregu sedanje akumulacije Ajba pod cesto Avče - Kanal in pod železniško progo Nova Gorica - Jesenice, kmalu po pritoku potoka Avšček v Sočo pod zgradbo železniške čuvajnice. V podlagi prevladuje flišni lapor, vložki apnenih breč in peščenjakov so bili podrejeni. Na mestu bodoče strojnice ni več pravih naravnih habitatov.

4. V poročilu o vplivih na vodno okolje smo obravnavali akumulacijo Ajba in reko Soča pod pregrado Ajba. Pregrada Ajba leži 4.5 km dolvodno od elektrarne Doblar in je betonska s tremi pretočnimi polji. Odvzem vode med pregrado Ajba in HE Plave je na dolžini 7950 m. Na podlagi raziskav v letu 2003 sodi akumulacija Ajba v 1. do 2. kakovostni razred. V reki Soči se pod pregrado Ajba že od leta 1996 izvaja stalni monitoring fizikalno-kemijskih in bioloških parametrov. Vrednosti BPK5, KPK, nitrati in celotni dušik so bile občasno povečane na vseh odvzemnih mestih pod pregrado Ajba. Glede na vrednosti saprobnega indeksa smo reko Sočo lahko uvrščali na tem odseku v 1 - 2. kakovostni razred.

Soča na obravnavanem odseku akumulacije Ajba in dolvodno spada v Goriški ribiški okoliš (Odredba o določitvi ribiških okolišev, Uradni List LR Slovenije, št. 17/59) v katerem z ribjimi populacijami upravlja Ribiška družina Soča Nova Gorica. Po podatkih ribiškega katastra v reki Soči na obravnavanem odseku živi 6 ribjih vrst in 1 križanec, med katerimi je iz vidika varovanja najpomembnejša soška postrv.



Slika 1 Položaj akumulacije Kanalski vrh, cevovoda in strojnice

3. METODOLOGIJA PRESOJE

V poročilu o vplivih na okolje smo obdelali naslednje segmente, ki podajajo okoljsko informacijo danega območja:

- opis vplivnega območja
- opis projekta
- opis vplivov in presoja vplivov
- relavantni zakonski in administrativno okvir.

V poročilu o vplivih na okolje smo obravnavali naslednje vplive v času gradnje in v času obratovanja:

Naravno okolje: geografske značilnosti, geosfera in tla, hidrosfera – podzemne vode, površinske vode (hidrologija, vodni biotop in biocenoza, ribe), kopenska favna, kopenska flora, klima in ozračje, hrup, prah in sevanje.

Kulturno in družbeno okolje: vidno okolje, varnost pregrade, bivalna kakovost – psihološki vidik, kmetijstvo in razvoj podeželja.

Za ocenjevanje vplivov smo uporabili šest stopenjsko lestvico, z ocenami, ki pomenijo naslednje:

Stopnja vpliva	Opisna ocena	Pojasnilo
+	pozitiven vpliv	Poseg bo pozitivno vplival na element okolja.
0	ni vpliva	Sprememba sestavine okolja je neugotovljivo majhna
1	vpliv je zanemarljiv	Fizična sprememba in kakovost prizadete sestavine je neznatna in zanemarljiva.
2	vpliv je zmeren	Vpliv na sestavino je znaten, vendar bodisi zaradi obsega fizične spremembe ali zaradi njene kakovosti ni posebno velik.
3	vpliv je hud	Vpliv je ocenjen kot zelo velik, vendar ni uničujoč in je še znotraj dopustnih meja.
4	vpliv je nedopusten	Vpliv je za sestavino okolja uničujoč, intenziteta vpliva presega z zakonom predpisane meje.

Ocena vpliva posega na posamezen element okolja je odvisna od stanja elementa pred posegom, obsega spremembe ter odnosa presojevalca do tega elementa. Za nekatere elemente obstajajo zakonsko določene mejne vrednosti obremenitev, za ostale pa je ocena vpliva rezultat strokovne presoje ocenjevalca.

Za vsak element smo opravili presojo vplivov na okolje v času gradnje in v času obratovanja, za primer brez upoštevanja omilitvenih ukrepov in za primer z upoštevanjem omilitvenih ukrepov.

4. OPIS IN OCENA VPLIVOV

V nadaljevanju so prikazani rezultati presoje vplivov na okolje za posamezne segmente.

Geomorfologija

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
2	Vpliv je zmeren	2	Vpliv je zmeren

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
2	Vpliv je zmeren	2	Vpliv je zmeren

Geosfera in tla

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
3	Vpliv je hud	2	Vpliv je zmeren

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
2	Vpliv je zmeren	2	Vpliv je zmeren

Hidrosfera – podzemne vode

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
2	Vpliv je zmeren	2	Vpliv je zmeren

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
1	Vpliv je zanemarljiv	1	Vpliv je zanemarljiv

Hidrologija

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
2	Vpliv je zmeren	2	Vpliv je zmeren

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
2	Vpliv je zmeren	2	Vpliv je zmeren

Vodni biotop in biocenoza

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
3	Vpliv je hud	2	Vpliv je zmeren

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
3	Vpliv je hud	2	Vpliv je zmeren

Ribe

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
2	Vpliv je zmeren	2	Vpliv je zmeren

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
2	Vpliv je zmeren	2	Vpliv je zmeren

Kopenska favna

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
3	Vpliv je hud	3	Vpliv je hud

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
2	Vpliv je zmeren	2	Vpliv je zmeren

Kopenska flora

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
3	Vpliv je hud	3	Vpliv je hud

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
0	Ni vpliva	0	Ni vpliva

Klima in ozračje

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
1	Vpliv je zanemarljiv	1	Vpliv je zanemarljiv

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
1	Vpliv je zanemarljiv	1	Vpliv je zanemarljiv

Hrup

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
3	Vpliv je hud	2	Vpliv je zmeren

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
1	Vpliv je zanemarljiv	1	Vpliv je zanemarljiv

Prah

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
3-4	Vpliv je hud do nedopusten	3	Vpliv je hud

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
0	Ni vpliva	0	Ni vpliva

Sevanje

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
0	Ni vpliva	0	Ni vpliva

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
0	Ni vpliva	0	Ni vpliva

Vidno okolje

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
3	Vpliv je hud	2	Vpliv je hud

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
3	Vpliv je hud	2	Vpliv je zmeren

Varnost pregrade

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
0	Ni vpliva	0	Ni vpliva

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
2	Vpliv je zmeren	2	Vpliv je zmeren

Bivalna kakovost – psihološki vidik

Ocena v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
2- 3	Vpliv je zmeren do hud	2- 3	Vpliv je zmeren do hud

Ocena v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
2- 3	Vpliv je zmeren do hud	2- 3	Vpliv je zmeren do hud

Kljub temu, da je splošna ocena vpliva na bivalno kakovost zmerna do huda, pa je potrebno povdariti, da so prisotni pozitivni vplivi (+), kot je pridobitev infrastrukture, sodelovanje s krajani ter možne rekreativne uporabe.

Kmetijstvo in razvoj podeželja

Ocena vpliva v času gradnje

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
2 -3	Vpliv je zmeren do hud	2-3	Vpliv je zmeren do hud

Ocena vpliva v času obratovanja

Brez omilitvenih ukrepov		Po izvedenih omilitvenih ukrepih	
stopnja vpliva	ocena	stopnja vpliva	ocena
+	Pozitiven vpliv	+	Pozitiven vpliv

Na podlagi rezultatov presoje vplivov na okolje smo ocenili, da je izgradnja ČHE Avče v okviru predvidenih ukrepov in priporočil z vidika varovanja okolja sprejemljiv poseg za okolje.

5. VAROVANJE IN NAČRT MONITORINGA

Za zmanjšanje negativnih vpliov na okolje smo podali rešitve in ukrepe za varovanje okolja, ohranjanja narave, varstva kulturne dediščine ter trajnostne rabe naravnih dobrin.

Med številnim ukrepi za varovanje okolja bi omenili le nekatere. Med gradnjo in po njej bi se morali izogibati večjemu poseganju v strugo Avščka, kjer zaradi močnih erozijskih procesov v zaledju potekajo zelo intenzivni procesi rečnega transporta in akumulacije, in hkrati ohraniti star kamnit most prek Avščka tik pred njegovim izlivom v Sočo, po možnosti pa most v okviru ureditve okolice strojnice po koncu gradnje tudi sanirati in mu dati določeno namembnost. Ukrepi v času gradnje predvidevajo predvsem onemogočanje povzročitve onesnaženja z mazivi in olji delovnih strojev, ter strokovno izvedbo oz. realizacijo projekta izgradnje. Delovni stroji, s katerimi se bodo izvajala gradbena dela, morajo biti tehnično brezhibni. Posegi v reko Sočo naj bodo omejeni na najmanjšo mero; dela naj se izvajajo kolikor mogoče hitro, da se motnje omejijo na najkrajši čas.

Med ukrepi za zmanjšanje negativnega vpliva na vodni in obvodni ekosistem reke Soče je potrebno:

- Zmanjševanje vtoka vseh hranilnih snovi, posebej fosfata in nitrata.
- Preprečiti odlaganje odvečnega materiala v strugo ali v neposredni bližini struge
- Pri začasnih ureditvah poti in delovišč je potrebno poskrbeti za takšen način odvodnjavanja, ki bo preprečil vnos materiala in nevarnih snovi v vodotoke.
- Za varovanje rastlinstva v okolici posegov so nujni splošni varstveni ukrepi (preprečevanje onesnaženja).
- Na območju akumulacije je potrebno preprečiti iztekanje vseh odpadnih vod v akumulacijo. Pred polnjenjem akumulacije morajo biti zgrajeni vsi kanalizacijski sistemi in čistilne naprave za odpadne vode.

Podani so bili številni ukrepi za zmanjševanje hrupa in emisij ter za zmanjšanje vplivov na kulturno in družbeno okolje.

Pri opredelitvi možnih vplivov ter določitvi načina izvedbe monitoringa smo upoštevali izsledke, mnenja in priporočila do sedaj opravljenih študij, pogoje iz lokacijskega načrta, veljavno zakonodaja ter prakso in izkušnje pri izvedbi podobnih projektov.

Namen monitoringa je identifikacija, spremljanje in ugotovitev trendov pojavov nastalih kot posledica gradnje in obratovanja ČHE Avče. Rezultati monitoringa bodo služili za določitev gradbenega in obratovalnega režima ČHE Avče ter nujnih ukrepov za preprečitev pojavov nevarnih in škodljivih za okolje. Opazovanja se delijo na:

- opazovanje izhodiščnega stanja,
- opazovanja med izgradnjo,
- opazovanja za ugotovitev trendov po začetku obratovanja,
- redno (operativno) opazovanje.

V letu 2006 smo začeli z izvedbo monitoringa v času gradnje. Vzorčevali smo v vodnem in obvodnem okolju reke Soče ter izvajali monitoring bivalnega okolja.

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Zakon o varstvu okolja (Ur. l. RS, št. 41/04)

Zakon o vodah (Ur. list RS št. 67/02, 110/02)

DOLOČANJE CONE MEŠANJA Z UPORABO PROGRAMSKEGA PAKETA CORMIX PRI TOČKOVNIH VTOKIH V VODNO TELO

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POVZETEK

Programsko orodje CORMIX omogoča grafičen prikaz širjenja koncentracije snovi v recipientu zaradi točkovnega vtoka v različnih vrstah vodnih teles. V prispevku je opisano teoretično ozadje delovanja programa, podkrepljeno s praktičnim primerom temperaturnega onesnaženja.

SUMMARY

CORMIX is mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones resulting from continuous point source discharges. Article is about theoretical background of model and real problem of temperature impact of point source as well.

1. UVOD

Človek z razvojem svojih dejavnosti posledično povzroča onesnaženje, ki degradira njegovo okolje. Če se omejimo na vire onesnaženja v vodnem okolju, lahko vrste onesnaženja delimo na točkovne in razpršene vire. Med razpršene vire spadajo večinoma posledice kmetijske dejavnosti, med točkovne pa točkovni vtoki iz čistilnih naprav, industrije, energetskih objektov...

Onesnaženi točkovni vtoki vsebujejo koncentracijo snovi (npr. hranila, toplota, težke kovine, suspendirane snovi), ki se izlivajo v recipient kot površinski ali podvodni vtok. Oceno širjenja polutanta oziroma koncentracije le-tega ob izlivu ter območje vpliva ob vtoku polutanta (cona mešanja) je mogoče določiti z matematičnim modelom, kar omogoča programsko orodje CORMIX.

2. OPIS PROGRAMSKEGA ORODJA CORMIX

2.1 Slošni opis

Programsko orodje CORMIX omogoča oceno prikaza širjenja koncentracije snovi v recipientu zaradi točkovnega vtoka v različnih vrstah vodnih teles. Le-ta so lahko omejena (bounded) ali neomejena (unbounded) in zajemajo:

- manjše vodotoke,
- reke,
- jezera,
- rečne akumulacije,
- estuarje,
- priobalno morje,

pri čemer se lahko upošteva tudi vpliv plimovanja oziroma nihanje vodne gladine zaradi delovanja hidroelektrarne.

Vrste točkovnih vtokov glede na način vnosa, ki jih program lahko obravnava, so:

- površinski vtok,
- podvodni izpust z enim difuzorjem,
- podvodni izpust z več difuzorji,

glede na svoje lastnosti pa so lahko:

- konservativni (med mešanjem niso podvrženi procesom odmiranja/rasti),
- nekonservativni (razpad/rast prvega reda),
- toplotni.

V splošnem je proces mešanja odvisen od razmer v recipientu ter lastnosti onesnaženega pritoka. Parametri, ki v največji meri vplivajo na proces mešanja v

prejemniku, so geometrijski (tlorisna površina, vertikalni profil, globina) ter dinamični (hitrosti, gostota vode - posebno v okolici vtoka). Zaradi reda velikosti procesa mešanja, ki traja v povprečju od nekaj minut do maksimalno ene ure, se v recipientu lahko v večini primerov predpostavi stalni enakomerni tok.

Najpomembnejši parametri vtoka, ki vplivajo na mešanje, zavisijo od tipa vtoka:

- podvodni izpust z enim difuzorjem: premer cevi na iztoku, oddaljenost od dna, orientacija v prostoru,
- podvodni izpust z več difuzorji: razporeditev difuzorjev vzdolž cevi, orientacija v prostoru,
- površinski vtok: presek kanala, orientacija v prostoru

ter od lastnosti vtoka:

- pretok,
- pretok gibalne količine (momentum flux),
- vzgonski pretok (buoyancy flux).

Slednji predstavlja razliko med gostoto vode v pritoku in recipientu in je odvisen od gravitacijskega pospeška.

V nadaljevanju je poudarek na podvodnem in površinskem vtoku

2.2 Omejitve

Omejitev programa (subjektivna ocena) so:

- omejitev števila pritokov na en sam točkovni vtok,
- konstantna gostota numerične mreže vzdolž trajektorije,
- časovna omejitev za vtok ali spremembe pretoka vtoka po času ni možna,
- ni možnosti prikaza rezultatov po prečnih prerezih,
- vpliv vetra je podan samo s hitrostjo, ne pa tudi s smerjo.

2.3 Enačbe

Programski moduli v vzdolžni smeri rešujejo kontinuitetno in dinamično enačbo vzdolž trajektorije curka, povzročene zaradi točkovnega vtoka. V prečni smeri je privzeta porazdelitev koncentracije snovi po Gaussu.

2.4 Cone mešanja

2.4.1 Cona ena (near field)

Najpomembnejši procesi, ki vplivajo na proces mešanja v prvi coni, neposredno ob izpustu, so mešanje zaradi podvodnega vtoka, mešanje zaradi površinskega vtoka in vpliv meje modela.

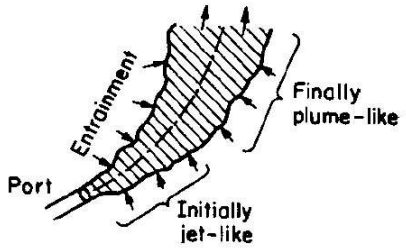
<u>Podvodni vtok</u>

»Čisti curek (predpostavljene enake gostote vtoka in prejemnika)« v trenutku vtoka v sprejemnik zaradi velike hitrosti povzroči turbulentno mešanje. V primeru različne gostote med vtokom in prejemnikom so turbulence posledica

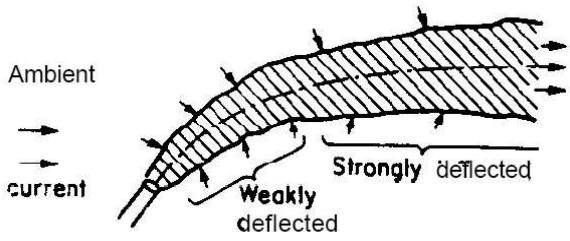
vzgonskega pretoka. V realnosti se največkrat srečujemo s kombinacijo obeh variant.

V mirujoči vodi je oblika območja turbulence odvisna od orientacije vtoka in smeri gravitacijskega pospeška (slika 1), v enakomernem toku pa poleg navedenega k obliki prispeva še hitrost vode recipienta (slika 2).

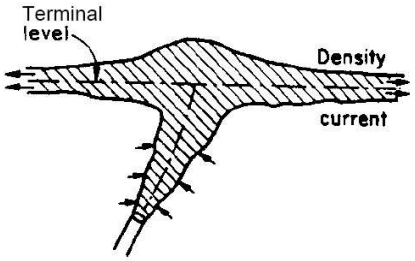
Proces mešanja zaradi neprekinjenega vtoka točkovnega vira v receptor je razdeljen na dve coni. To sta cona ena (near field) ter cona dve (far field). V prvi coni določajo vpliv na mešanje in obliko trajektorije lastnosti curka. Z oddaljenostjo od točke vtoka se vpliv lastnosti, ki pomembno vplivajo na mešanje, zmanjšuje. Na proces mešanja in obliko trajektorije v drugi coni pričnejo vplivati lastnosti receptorja.



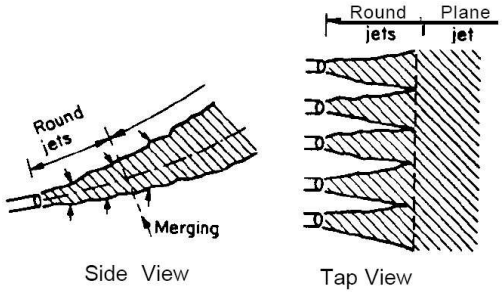
Slika 1 Oblika območja turbulence v mirujoči vodi



Slika 2 Oblika območja turbulence zaradi delovanja vodnega toka



Slika 3 Oblika območja turbulence stratificiranem vodotoku, v mirujoči vodi

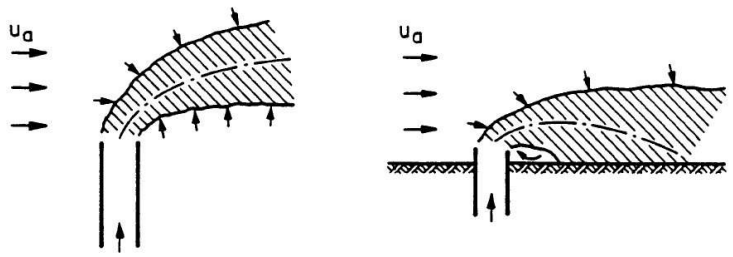


Slika 4 Oblika območja turbulence za iztok z več difuzorji, enako usmerjeni

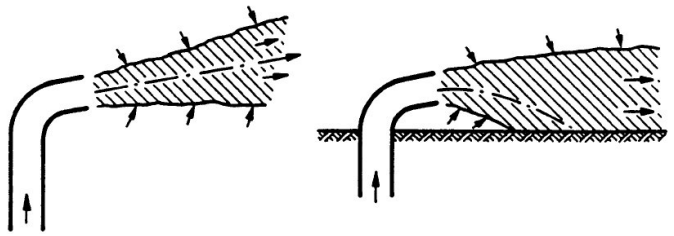
V stratificiranem vodotoku spremembe v gostoti nasprotujejo smeri vzgona, preprečijo nadaljnje vertikalno gibanje ter povzročijo, da se tok »ujame« na določeni globini (slika 3). Podvodni izpust okrogle oblike v primeru iztoka z več difuzorji se obnaša kot enojni; na določeni razdalji pride do interakcije in skupina difuzorjev deluje kot ravninski curek.

Vpliv meje modela

Meje modela vplivajo na proces mešanja, tako v prvi kot tudi v drugi coni. V prvem primeru (slika 5) meja modela povzroči recirkulacijo (wake attachment) dolvodno od vtoka. V drugem primeru meja modela zaradi izpusta, vzporednega meji modela, zaradi podtlaka povzroči lepljenje curka ob steno (Coanda attachment, slika 6).



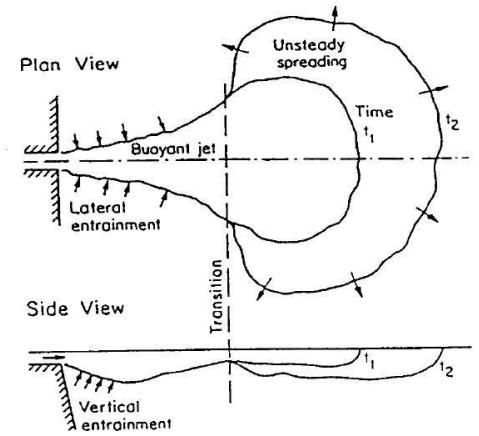
Slika 5 Pojav recirkulacije zaradi, vtok pravokotno na mejo modela



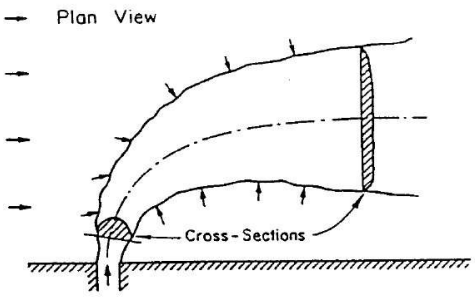
Slika 6 Pojav prilepljenja curka zaradi pojava podtlaka, vtok vzporeden z mejo modela

Površinski vtok

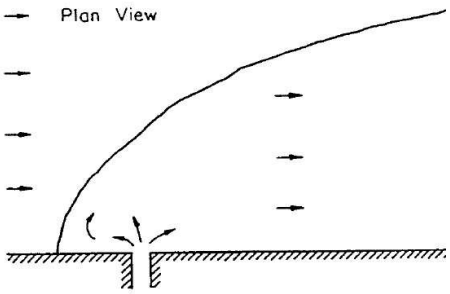
Površinski vtok, ki se izliva v vodotok horizontalno (slika 7), s pozitivno usmerjenim pospeškom (vzgon), se obnaša podobno kot podvodni izpust. Na relativno kratki razdalji se obnaša kot curek in se zaradi turbulence širi v vodno telo v prečni ter vertikalni smeri. Na slikah od 7 do 10 so prikazane štiri najbolj tipične oblike mešanja zaradi površinskega vtoka.



Slika 7 Oblika območja mešanja, površinski vtok, mirujoča voda



Slika 8 Oblika območja mešanja, površinski vtok, majhna hitrost vodotoka

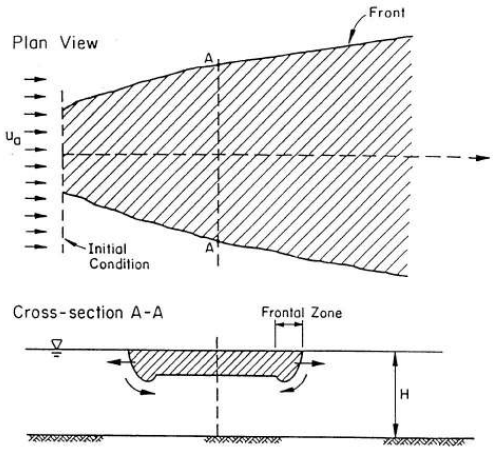


Slika 9 Oblika območja mešanja, površinski vtok, zelo majhna hitrost vodotoka

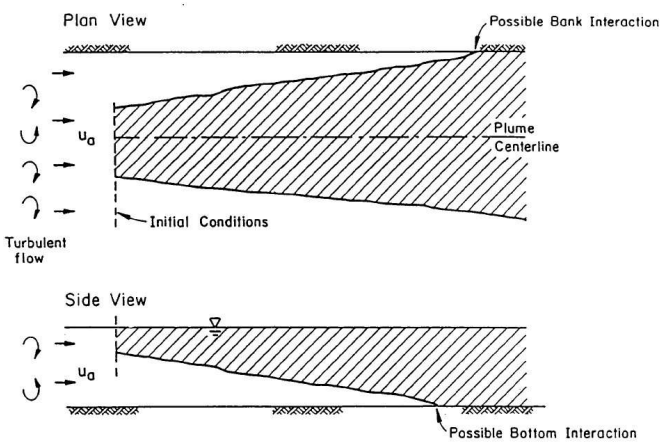
Slika 10 Oblika območja mešanja, površinski vtok, zelo majhna hitrost v reki (tovarna pletenin Impoljca) Foto: A. Sedej

2.4.2 Cona dve (far field)

V coni dve se območje mešanja širi navzdol s tokom, hkrati pa poteka tudi mešanje v prečni smeri. V odvisnosti od gostote v območju obravnave se generalno ločita dva načina mešanja. Če je vodotok stratificiran se, v odvisnosti od gostote obravnavanega območja, le-ta širi po površini vodotoka ali pa je ujet v stratificirani coni (slika 11). V nasprotnem primeru, če vodotok ni stratificiran in je razlika med gostotama vodotoka in »madeža« neznatna, pride do t.i. pasivne oblike mešanja (slika 12).



Slika 11 Oblika širjenja »madeža« v drugi coni



Slika 12 Pasivna oblika mešanja

2.4.3 Cone mešanja - osnovni pojmi

Glede na definicijo dokumenta EPA (Environmental and pollution agency) »The clean water act« ločimo 5 vrst polutantov:

- konvencionalni (podvrženi biološkemu razkroju),
- nekonvencionalni (niso strupeni ali konvencionalni),
- strupeni (povzročajo akutne ali kronične zastrupitve živih organizmov),
- toplotni,
- iztoki iz drenaž.

Onesnaženi pritok, gledano v širšem pomenu, ne sme kvariti kvalitete vode, v katero se steka. Gledano lokalno pa morajo biti začetne koncentracije polutanta oziroma vplivi na neposredno okolico vtoka v največji možni meri zmanjšani in omejeni na čim manjše območje in volumen.

3. PRAKTIČNI PRIMER UPORABE MODELA

Praktična uporaba modela je bila izvedena na preprostem primeru modeliranja podvodnega toplotnega izpusta v rečno akumulacijo.

3.1 Vhodni podatki

Vhodni podatki za delo z modelom se na terenu vpišejo v popisni list (slika 13) na podlagi ocene ali meritve, vnesejo pa se na podlagi uporabniku prijaznih menijev (slika 14):

- splošni opisni podatki
- podatki o receptorju (geometrija, hitrost, n_G, gostota vode)
- podatki vtoka (hitrost, koncentracija snovi, gostota, temperatura...)
- podatki vtoka (geometrija, orientacija v prostoru)
- cona mešanja, dolžina odseka, željeno stanje kvalitete prejemnika (water quality standard)

CHECKLIST FOR DATA PREPARATION

CORMIX -- CORNELL MIXING ZONE EXPERT SYSTEM -- Version 3.00-3.20

SITE Name _____ Date:
Design **CASE** _____ Prepared by:
DOS **FILE NAME** _____ (w/o extension)

AMBIENT DATA: Water body is bounded/unbounded
Water body depth _____ m If bounded: Width _____ m
Depth at discharge _____ m Appearance 1/2/3
If steady: Ambient flowrate _____ m^3/s or: Ambient velocity _____ m/s

If tidal: Tidal period _____ hr Max. tidal velocity _____ m/s
At time _____ hr before/at/after slack: Tidal velocity at this time _____ m/s

Manning's n _____ or: Darcy-Weisbach f _____
Wind speed _____ m/s
Density data: UNITS: Density...kg/m^3 / Temperature...°C
Water body is fresh/salt water If fresh: Specify as density/temp. values
If uniform: Average density/temp. _____

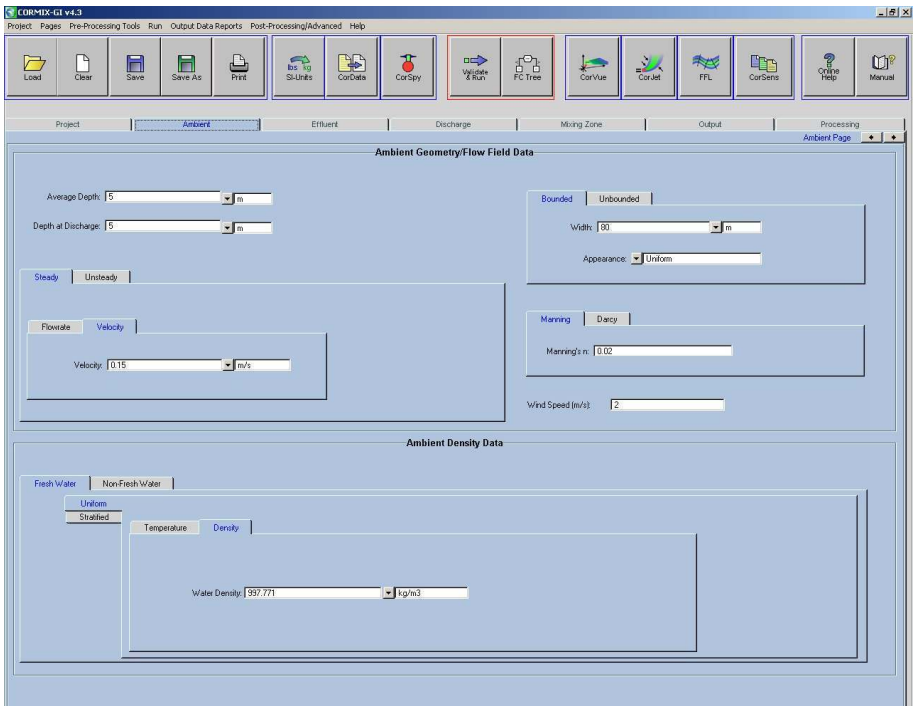
If stratified: Density/temp. at surface _____
Stratification type A/B/C Density/temp. at bottom _____
If B/C: Pycnocline height _____ m If C: Density/temp. jump _____

DISCHARGE DATA: Specify **geometry** for CORMIX1 or 2 or 3

SUBMERGED SINGLE PORT DISCHARGE -- CORMIX1
Nearest bank is on left/right Distance to nearest bank _____ m
Vertical angle THETA _____ ° Horizontal angle SIGMA _____ °
Port diameter _____ m or: Port area _____ m^2
Port height _____ m

SUBMERGED MULTIPORT DIFFUSER DISCHARGE -- CORMIX2
Nearest bank is on left/right Distance to one endpoint _____ m

Slika 13 Popisni list za pripravo vhodnih podatkov



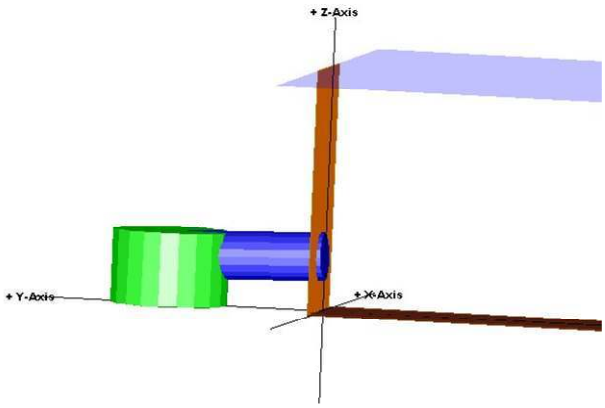
Slika 14 Prikaz menija – vnosnih polj za delo s programom

V končni fazi je za račun podvodnega točkovnega vtoka potreben nabor podatkov, prikazan v sliki 15.

Vodotok – reka Sava	
povprečna globina	5m
globina na vtoku izpusta	5m
širina	80m
hitrost	0,15 m/s
temperatura (na dnu in na površini)	22°C
Manningov koeficient	0,02
hitrost vetra	2m/s
raven odsek reke	
gostota – glede na T vode (na dnu in na površini)	997,7714 kg/m3
Pritok	
hitrost	1,5 m/s
temperatura	34 °C
izguba toplote zaradi hitrosti vetra, glede na temperaturo vode v prejemniku (Sava)	15 W/m2/°C
lega pritoka	levi breg, 0.1m od brežine, pravokotno na brežino
oddaljenost od dna	1m
premer odprtine (okrogla)	1m
horizontalni naklon cevi	2°
gostota – glede na T vode	994,3696 kg/m3
WQ standard	24°C
Mixing zone	10m
X-os	1000m

Slika 15 Nabor podatkov za račun točkovnega vtoka

Pred pričetkom računa so na voljo podatki o načinu vtoka ter vizualizacija vtoka s programskim modulom CorVue 3-D (slika 16). Prav tako se pred zagonom računa požene programski modul CORSPY, ki preveri pravilnost vnosa podatkov (morebitno neizpolnjevanje pogojev programa, pomanjkanje podatkov).

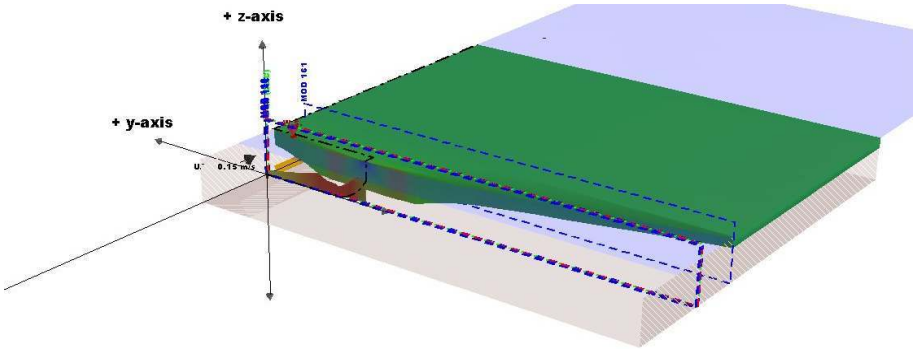


Slika 16 Grafični izris vtoka

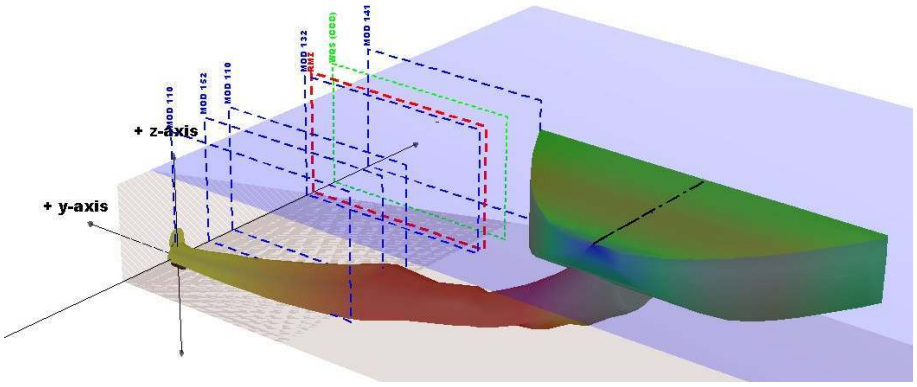
3.2 Rezultati modela in komentar rezultatov

Prikaz rezultatov modela je možen v tekstualni in grafični obliki. V tekstualni obliki se rezultati modela izpišejo kot številčne vrednosti, v grafični

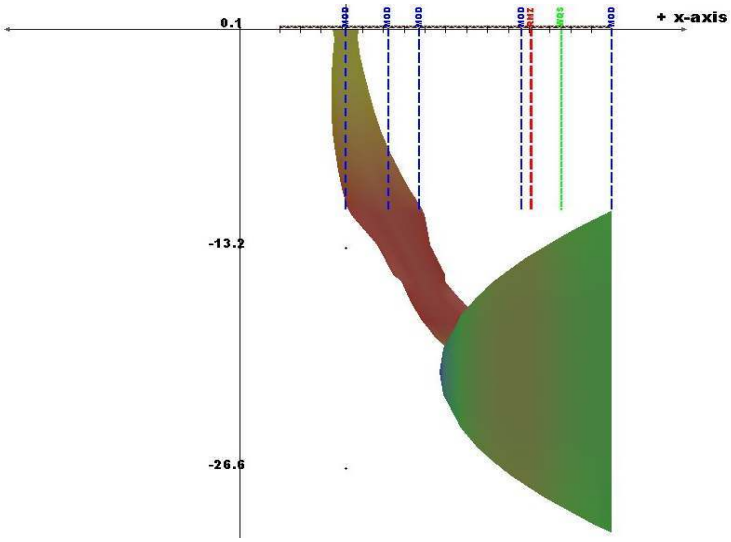
obliki (Slika 17 in18) pa so številčne vrednosti prikazane v obliki diagramov, 2-D in 3-D risb z barvno lestvico. V slikovnem prikazu je možen prikaz iz različnih zornih kotov ter v različnih razmerjih osi x:y:z, pri čemer os-x pomeni smer toka vodotoka.



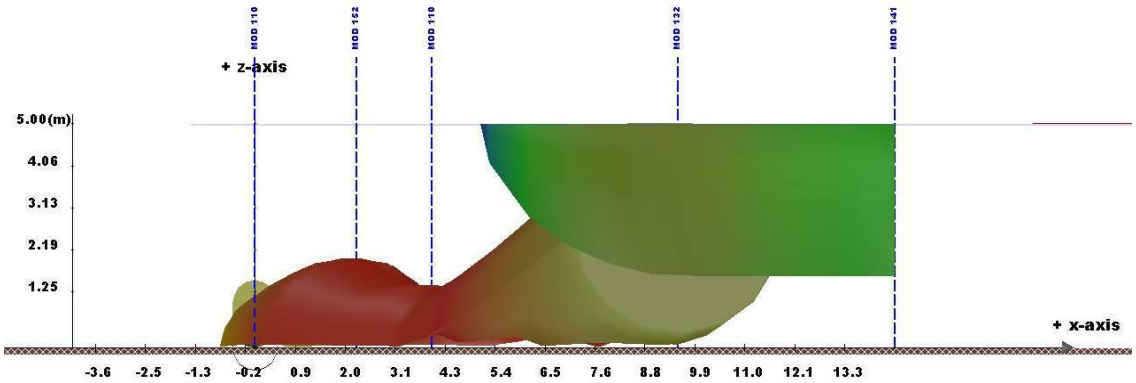
Slika 17 3-D Oddaljen pogled na celoten obravnavani odsek v dolžini 1000m, y:x=17:24 (far field)



Slika 18 Pogled na odsek v neposredni bližini vtoka (near field)



Slika 19 Pogled v Y-X osi, Y:X=1:1



Slika 20 Pogled v Z-X osi, Z:X=1:1, 20,70m od levega brega

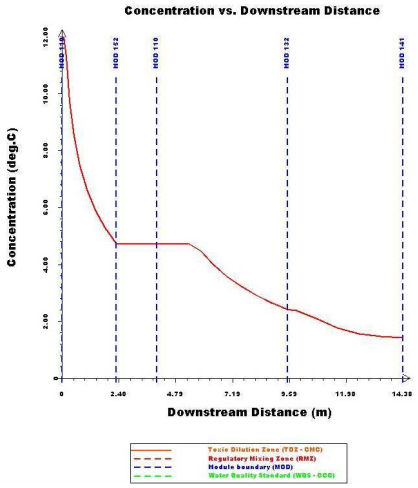
Koncentracija snovi (Slika 17-20)

Koncentracija snovi, oziroma v našem primeru temperatura, je prikazana kot delta temperature glede na začetno okoliško temperaturo.

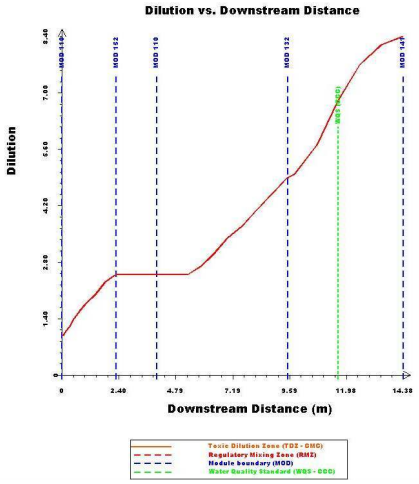
Program omogoča grafični prikaz rezultatov v obliki diagramov za:

- koncentracijo snovi (Slika 21) ali razredčenje (Slika 22) kot funkcijo vzdolž struge vodotoka
- koncentracijo snovi (Slika 23) ali razredčenje (Slika 24) vzdolž trajektorije - prostorske krivulje, ki opisuje pot curka.

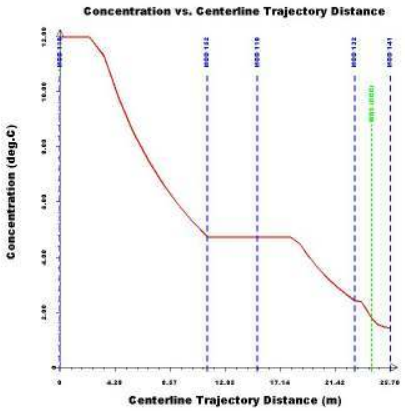
Iz grafičnih rezultatov lahko razberemo, da je temperatura vode tudi po 1000m in ob danih začetnih pogojih (Slika 15) še vedno nad temperaturo okoliške vode. Zanimalo nas je tudi na kateri razdalji od mesta točkovnega vtoka bo dosežena dosežena temperatura 24°C (water quality standard) - odgovor je razviden iz diagrama - po 10,7m.



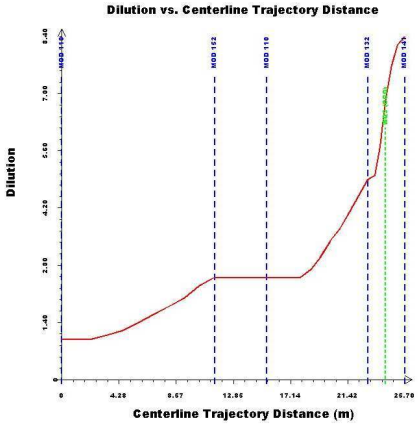
Slika 21 Koncentracija (temperatura delta T) kot funkcija razdalje od točke vtoka navzdol, po osi X



Slika 22 Razredčenje kot funkcija razdalje od točke vtoka navzdol, po osi X



Slika 23 Koncentracija (temperatura delta T) kot funkcija razdalje od točke vtoka vzdolž trajektorije



Slika 24 Razredčenje kot funkcija razdalje od točke vtoka vzdolž trajektorije

4. ZAKLJUČEK

Program CORMIX je enostavno in uporabniku prijazno orodje, s katerim se lahko hitro oceni vpliv različnih vrst vtokov v vodno telo še pred procesom natančnega, zahtevnega in časovno zamudnega modeliranja z 2-D ali 3-D modeli. Primerjava z verificiranim 3-D modelom je pokazala sorazmerno veliko odstopanje rezultatov, zato smatram, da CORMIX vsekakor ni orodje, ki bi lahko zadostilo strokovnemu delu na področju hidrotehnike.

POSODOBITEV SEIZMIČNEGA MONITORINGA NA PREGRADI VOGRŠČEK

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ARSO, Ljubljana

POVZETEK

Vsako leto v Zemljini notranjosti nastane več močnih potresov z obsežnimi posledicami tudi na večjih objektih. Mednje štejemo tudi velike pregrade, od katerih so mnoge zgrajene na potresno aktivnih območjih. Za presojo projektnih obtežb in obnašanja pregradnih objektov smo se v Sloveniji odločili, da je za zagotavljanje varnosti pregrad treba nadaljevati z opazovanjem njihove seizmičnosti. V Uradnem listu RS je bil leta 1999 objavljen Pravilnik o opazovanju seizmičnosti na območju velikih pregrad, ki predpisuje načine opazovanja seizmičnosti, tehnične normative seizmoloških instrumentov ter pogoje, ki jih mora izpolnjevati izvajalec opazovanja vpliva seizmičnosti na velike pregrade. Pregrada Vogršček glede na svojo gradbeno višino in prostornino zajezene vode, sodi med velike pregrade, za katere se zahteva seizmično opazovanje. Primerjava sistema za seizmično opazovanje na pregradi z zahtevami, ki jih predpisuje pravilnik, je pokazala, da sistem novim zahtevam ne ustreza. Leta 2002 je Sektor za upravljanje z vodami pri Agenciji RS za okolje vzpostavil projekt posodobitve seizmičnega opazovanja pregrade Vogršček. Novi sistem je bil v celoti nameščen in vključen v obratovanje konec leta 2005.

SUMMARY

There are many strong earthquakes on our planet every year. They cause extensive damage to large structures, such as large dams, which are often built in active seismic regions. To estimate seismic actions and their consequences on dams, we decided it was necessary to continue seismic monitoring of dams in order to be sure of their safety. The regulation on seismic monitoring of large dams was issued in the National Gazette in 1999. It regulates seismic monitoring methods, technical standards for seismological equipment, conditions which must be fulfilled by the performer of the seismic monitoring and also defines the concept of large dams.

Vogršček dam belongs among large dams taking into account its height and volume of accumulated water and seismic monitoring is required. The comparison of the parameters of the installed monitoring system with the regulations has shown, that system has not suit the new requirements. In 2002 The Water Management Section at Environmental Agency of the Republic of Slovenia started with project of modernization of the seismic monitoring on Vogršček dam. The new system was completely installed and started up at the end of 2005.

1. UVOD

Letno je na Zemlji zabeleženih prek 3 milijone potresov. Večina je tako šibkih, da jih ljudje ne čutimo. Toda vsaj 900 potresov letno je močnejših od magnitude 5. Takšni potresi lahko povzročajo tudi obsežne posledice. Od leta 1900 je v potresih izgubilo življenja prek 1,6 milijona ljudi, posledice potresov pa v posameznih državah pomenijo pravo gospodarsko katastrofo. Mnoge pregrade po svetu so zgrajene na potresno aktivnih območjih in po znanih podatkih je 74 pregrad utrpelo poškodbe zaradi potresov, od tega 27 pregrad hude ali zelo hude poškodbe. Zaradi potresa so tako utrpele poškodbe tudi nam bližnje pregrade v Makedoniji, Romuniji in Veliki Britaniji.

Sestavni del ocene potresne nevarnosti območij in lokacij pregradnih objektov je opazovanje seizmičnosti pregradnih objektov, ki je tudi bistveno za presojo potresne odpornosti objektov. Tako dobljeni podatki omogočajo smotrne projektne odločitve pri novogradnjah, pri obstoječih pregradah pa omogočajo čim stvarnejše odločitve pri popravilih ali ojačevanjih po morebitnih poškodbah zaradi potresov. Zapisi dejanskih potresov nam pomenijo edine prave rezultate, ki nam služijo za presojo projektnih obtežb, obnašanja in celovito oceno varnosti pregrad.

Na osnovi Pravilnika o tehničnih normativih za seizmično opazovanje visokih pregrad (UL SFRJ 6/88) in Zakona o varstvu okolja (UL RS 32/93) smo se zato v Sloveniji odločili, da je za zagotavljanje varnosti pregrad treba nadaljevati z njihovim potresnim opazovanjem. Pravilnik o opazovanju seizmičnosti na območju velikih pregrad, objavljen v Uradnem listu RS št. 92 leta 1999, predpisuje:

- način opazovanja inducirane seizmičnosti, ki jo povzroča voda v zbiralniku, zajezena z veliko pregrado,
- način opazovanja dinamičnega obnašanja telesa in temelja velikih pregrad, zbiralnikov oz. prostora za njimi in prostega površja v njihovi neposredni bližini ob delovanju potresov,

Namen pravilnika je zagotoviti opazovanje inducirane seizmičnosti in opazovanje dinamičnega obnašanja pregrade.

Opazovanje inducirane seizmičnosti pomeni zaznavanje in zapisovanje sprememb potresne dejavnosti, ki nastajajo zaradi vode v zbiralniku, zajezene v prostoru za veliko pregrado. Pojav potresov, ki so povezani s človeško dejavnostjo, imenujemo inducirana ali, pravilneje, trigerirana seizmičnost. Le-ta se manifestira v širokem prostorskočasovnem in energetskem razponu: od mikropotresov v neposredni bližini vira sprememb do rušilnih potresov z žariščem na globini, večji od desetih kilometrov. Eden od vzrokov za inducirano (trigerirano) seizmičnost so tudi vodna zajetja.

Zaenkrat sta ugotovljena dva možna mehanizma, ki lahko sprožita spremembo naravne seizmičnosti. V obeh primerih gre za motnje v naravnem napetostnem stanju. Teža vode v zajetju izvaja dodaten pritisk v vertikalni smeri. Potresi, sproženi s tem mehanizmom, so praviloma šibkejši (ker je masa vode tudi pri največjih zajetjih relativno majhna v primerjavi z maso kamnine pod zajetjem) in se pojavljajo kmalu (nekaj dni ali mesecev) po začetku polnjenja zajetja na majhnih globinah (do 3 km) in v neposredni bližini. Zelo pogosto je

število potresov povezano z višino vode ali s hitrostjo polnjenja in praznjenja zajetja. V določenih pogojih je sprememba taka, da se naravna seizmičnost zmanjša. Tako je v pogojih, kjer je največja napetost vertikalna ali ima strm vpad, pričakovati pojav novih potresov (območja, v katerih prevladujejo normalni in zmični prelomi), ker teža vode poveča naravne napetosti. V območjih, v katerih je največja napetost horizontalna, je pogost pojav zmanjšanja naravne seizmičnosti, ker teža vode deluje nasprotno od naravnih pogojev.

Slika 1 Pregrada Vogršček je zgrajena na potoku Vogršček pri Vogrskem

Drugi mehanizem je povečanje pornega pritiska podzemnih voda, ki zmanjšuje upor kamnine ob prelomu proti zmičnim napetostim. Potresi, proženi na ta način, nastajajo v večjih globinah (tudi več kot 10 km), lahko tudi na večjih oddaljenostih (nekaj deset kilometrov) od vodnega zajetja. Ker voda potrebuje precej časa, da prodre do globin (odvisno od permeabilnosti kamnin), se taki potresi lahko prvič pojavijo tudi več let po polnjenju (do 20 let). Potresi večjih magnitud nastajajo ob večjih prelomih in njihov obstoj je predpogoj tudi za pojav potresov. Vodne zajezitve so praviloma v rečnih dolinah, ki so nastale z erozijo v območjih z aktivno tektoniko in jih večinoma sekajo številni prelomi. Dinamika pojava trigerirane seizmičnosti je lahko različna. Zaenkrat so spoznali nekaj »tipičnih« obnašanj:

- potresi takoj po polnjenju (najbolj pogosti) so povezani s spremembo nivoja vode in se včasih prenehajo ponavljati po nekaj letih,
- stalni potresi (redkejši pojav) kažejo na stalno spremembo seizmičnosti,
- seizmičnost v kraških območjih, ki je včasih tudi povezana z zelo majhnimi zajetji,
- aseizmična zajetja, pri katerih pride do zmanjšanja potresne aktivnosti in – mešana, v katerih s časom pride do prehoda iz enega tipa v drugega.

Pojav inducirane seizmičnosti predstavlja nevarnost tako za sam jez kakor tudi za okolico. V primeru močnejšega potresa lahko pride do poškodb pregrade

in iztekanja vode ali do plazov v vodno zajetje, ki hitro dvignejo vodno gladino in sprožijo vodni val. Tveganju so posebej izpostavljena območja z nizko naravno seizmičnostjo, kjer pregrade niso projektirane za močnejše potrese, kot je to praviloma v območjih z visoko seizmičnostjo in močnimi potresi v preteklosti.

Opazovanje dinamičnega obnašanja pregrade pa je zaznavanje in zapisovanje odziva telesa in temelja pregrade ter prostega površja okoli nje na potres. Z opazovanjem pridobi lastnik pregrade podatke o obnašanju določene pregrade med potresom. Ob močnejšem potresu se lahko odloči za podrobnejši pregled pregrade zaradi možnosti nastanka poškodb in se odloči za nadaljnje ukrepanje. Podatke lahko uporabimo tudi pri načrtovanju in vrednotenju novih pregrad. Baza podatkov zapisov dinamičnega obnašanja množice pregrad bo omogočila načrtovalcem zanesljivejšo oceno odziva pregrade na potres. Možno bo narediti analitično oceno obnašanja pregrade s primerjavo med izračunanim odzivom pregrade z dejanski, izmerjenim odzivom. Izboljšave analitičnih postopkov ocenjevanja bodo omogočile zanesljivejše analize varnosti obstoječih in tudi novih pregrad.Vsaka pregrada je edinstvena konstrukcija glede na velikost, obliko, material, iz katerega je zgrajena, konstrukcijo, temeljenje (kamnina podlage, oblika) in zunanji vplivi. Poznavanje konstrukcijskih načrtov in spremenljivih vplivov, ki lahko spremenijo lastnosti pregrade, so pomembni pri izbiri sistema instrumentiranja za posamezno pregrado. Raznovrstnost pregrad zahteva, da jih je čim več potrebno opremiti z instrumenti za seizmično opazovanje, tako da dobimo podatke o odzivu na potres za vse vrste pregrad. Za največji učinek meritev morajo biti instrumenti nameščeni tako, da z rezultati meritev lahko preverimo dinamično analizo lokacije in pregrade (Godec in sod., 2004).

2. ZADRŽEVALNIK VOGRŠČEK

Zadrževalnik Vogršček je bil zgrajen v letih 1986-1989 v okviru programa ureditvenih del za usposabljanje kmetijskih zemljišč za intenzivno kmetijsko proizvodnjo v Vipavski dolini. Pregrada je postavljena na potoku Vogršček, in je od izliva v potok Lisjak oddaljenim 3,7 km gorvodno.

Zadrževalnik je predviden za zadrževanje do 7.500.000 m3 vode. 6.500.000 m3 zadržane vode je predvideno za namakanje na planiranih 4000 ha kmetijskih zemljišč, za 1.500.000 m3 vode je z dvigom zapornice nad prelivom možno zagotoviti rezervo za prestrezanje poplavnega vala in tako za potrebe obrambe pred poplavami, približno 400.000 m3 vode pri napol praznem zadrževalniku pa predstavlja mrtvi prostor in vodno rezervo za potrebe ribogojništva pred popolnim izpraznjenjem zadrževalnika (preglednica 1).

Pregrada Vogršček glede na svojo gradbeno višino in prostornino zajezene vode, ki presegata vrednosti podane s Pravilnikom o opazovanju seizmičnosti na območju velike pregrade, sodi med velike pregrade, za katere se zahteva seizmično opazovanje. Po 13. in 14. členu pravilnika je za opazovanje dinamičnega obnašanja pregrade ob potresu potrebno na pregradi Vogršček vzpostaviti omrežje najmanj treh akcelerografov, od katerih je eden v temelju, drugi v telesu pregrade, tretji pa na prostem površju.

Tabela 1 Karakteristike zadrževalnika (Vir: http://slocold.ibe.si/).

ime pregrade	Vogršček
leto izgradnje	1988
vodotok	Vogršček
najbližji kraj	Vogrsko
tip pregrade	nasuta zemeljska
lega in tip tesnitve	neprepustno jedro
temeljenje	skala
konstruktivna višina	37 m
hidravlična višina	31 m
dolžina krone	200 m
prostornina pregrade	230.000 m^3
prostornina zajezitve	8.500.000 m^3
površina zajezitve	800.000 m^2
dolžina zajezitve	2,7 km
padavinsko območje	11 km^2
pretoki sr/ 1%/ 0,1%	0,26/ 48/ 71 m^3/s
kapaciteta preliva	30 preliv +35 talni izpust m^3/s
tip preliva	prosto prelivanje in zaklopka
lastnik	Ministrstvo za okolje in prostor
namen	namakanje, rekreacija, ribištvo, visokovodna zaščita

3. SISTEM ZA SEIZMIČNO OPAZOVANJE ISE 3

Na pregrado so leta 1993 namestili sistem za seizmično opazovanje dinamičnega obnašanja pregrade. Merilni sistem sta sestavljata dva akcelerografa ISE 3, ki ju je izdelalo podjetje DMS Data Merilni Sistemi d.o.o.. Prvi je bil nameščen v jašku ob robu pregrade, drugi pa v jašku na sredi krone pregrade. Akcelerograf so sestavljali triosni senzor pospeška z analognim ojačevalnikom, zajemalna enota z digitalizatorjem, časovno bazo in pomnilnikom za začasno shranjevanje zapisov dogodkov, vhodno-izhodna enota za povezavo z računalnikom in dolgovalovnim sprejemnikom točnega časa DCF77 ter napajalnik. Sklopi akcelerografa so bili vgrajeni v robustno vodotesno kovinsko ohišje, ki je bilo s štirimi vijaki pritrjeno na podlago. Zbiranje podatkov iz obeh enot, nastavljanje parametrov in nadzor delovanja je potekalo z osebnim računalnikom.

Primerjava sistema za seizmično opazovanje z zahtevami, ki jih predpisuje Pravilnik o opazovanju seizmičnosti na območju velike pregrade, je pokazala, da sistem novim zahtevam ne ustreza. Premajhno število akcelerografov, njihove neustrezne tehnične lastnosti in tudi neprimerni lokaciji postavitve zahtevajo zamenjavo sistema za seizmično opazovanje pregrade z novim, ki bo nameščen na novih lokacijah (.

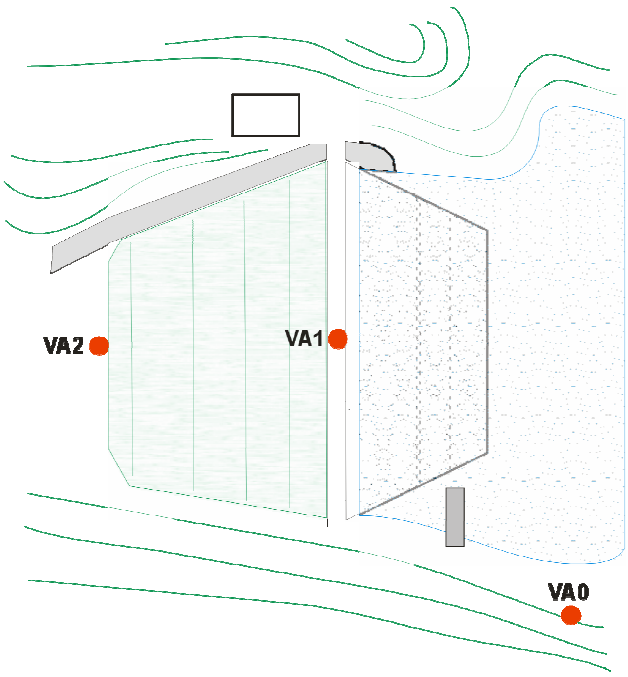
Velikost pregrade zahteva opazovanje seizmičnosti s tremi instrumenti. Prav tako ne odgovarjajo zahtevam lokacije instrumentov in nekatere tehnične zahteve:

- premajhna resolucija A/D pretvornika in s tem premajhno dinamično območje instrumenta
- vzorčenje vseh treh kanalov posameznega instrumenta ni istočasno
- premajhen pomnilnik
- ni večopravilnosti
- nastavitev preddogodkovnega in podogodkovnega časa
- ni možna nastavitev parametrov za vsak kanal posebej

4. POSODOBITEV SEIZMIČNEGA OPAZOVANJA

Leta 2002 je Sektor za upravljanje z vodami pri Agenciji RS za okolje vzpostavil projekt posodobitve seizmičnega opazovanja pregrade Vogršček, Urad za seizmologijo in geologijo pa je pripravil projektno nalogo. Naslednje leto je IBE d.d. pripravil projekt, v začetku leta 2004 pa so bila izvedena gradbena dela (Brenčič, Širca, 2004). Zgrajeni so bili trije jaški (slika 2):

- na kroni pregrade za namestitev instrumenta na telesu pregrade,
- ob vznožju pregrade, za namestitev instrumenta v temelju pregrade
- na levi strani jezera, približno 100 m od pregrade, za namestitev instrumenta na prostem površju



Slika 2 Razporeditev instrumentov na pregradi

Jaški so zgrajeni tako, da je zagotovljen trden stik akcelerometra s podlago, to je s telesom pregrade pri inštrumentu VA1, ter z osnovno zemljino pri akcelerometrih za opazovanje prostega površja (VA0) in temelja pregrade (VA2).

Opazovalni sistem sestoji iz treh akcelerometrov EpiSensor ES-T in centralne enote K2 podjetja Kinemetrics Inc., zasnovane tako, da omogoča priklop od dveh do štirih akcelerometrov. Senzor pospeška je zaprto-zančnega tipa in ima tri, med seboj ortogonalne komponente (slika 3). Izhodni signal je proporcionalen pospešku tal. Ima kalibracijsko tuljavo, ki omogoča določitev frekvenčne prevajalne funkcije in možnost nastavitve/popravke offset napetosti vsake komponente posebej. Izhodna napetost senzorjev je usklajena z vhodno napetostjo zajemalne naprave.

Slika 3 Akcelerometer EpiSensor ES-T je z vijakom pritrjen na betonsko podlago v jašku

Vhodna enota je sestavljena iz ločenih analogno-digitalnih (AD) pretvornikov za vsak kanal, tako da je izpolnjen pogoj istočasnega vzorčenja signalov na vseh kanalih. Za lokalno shranjevanje podatkov je vgrajen programirljiv bralni pomnilnik (flash) velikosti 40 MB, kar zadostuje za registracijo 80 dogodkov. Vgrajeni GPS sprejemnik zagotavlja točnost časovnega sistema ± 0,5 ms. Za komunikacijo s sistemom uporabljamo protokol RS 232 preko COM vrat ali preko modemske povezave po klicni liniji. Izberemo lahko neprekinjeno zajemanje podatkov ali proženo zajemanje. Proženje je nastavljivo za vsak kanal posebej in je lahko notranje ali zunanje. Večopravilni operacijski sistem omogoča istočasno zajemanje vhodnih podatkov, nadzor sistema in prenos podatkov v središče za obdelavo. Možna je nadgradnja strojne programske opreme na daljavo. Nadzor sistema omogoča nastavitve frekvence vzorčenja, izbiro filtra, izbiro načina proženja, vzdržuje komunikacijo in nadzor pomnilnika. Nastavitve omogočajo avtomatsko komunikacijo ob zaznavi potresa ali napake na sistemu (izpad napajalne napetosti, GPS sprejemnika, spremembe temperature,

pomanjkanje prostega pomnilnika). Za neprekinjeno obratovanje v primeru izpada omrežne napetosti je vgrajena baterija, ki omogoča najmanj 36-urno avtonomno delovanje sistema. Ohišja centralne enote in akcelerometrov so vodotesna.

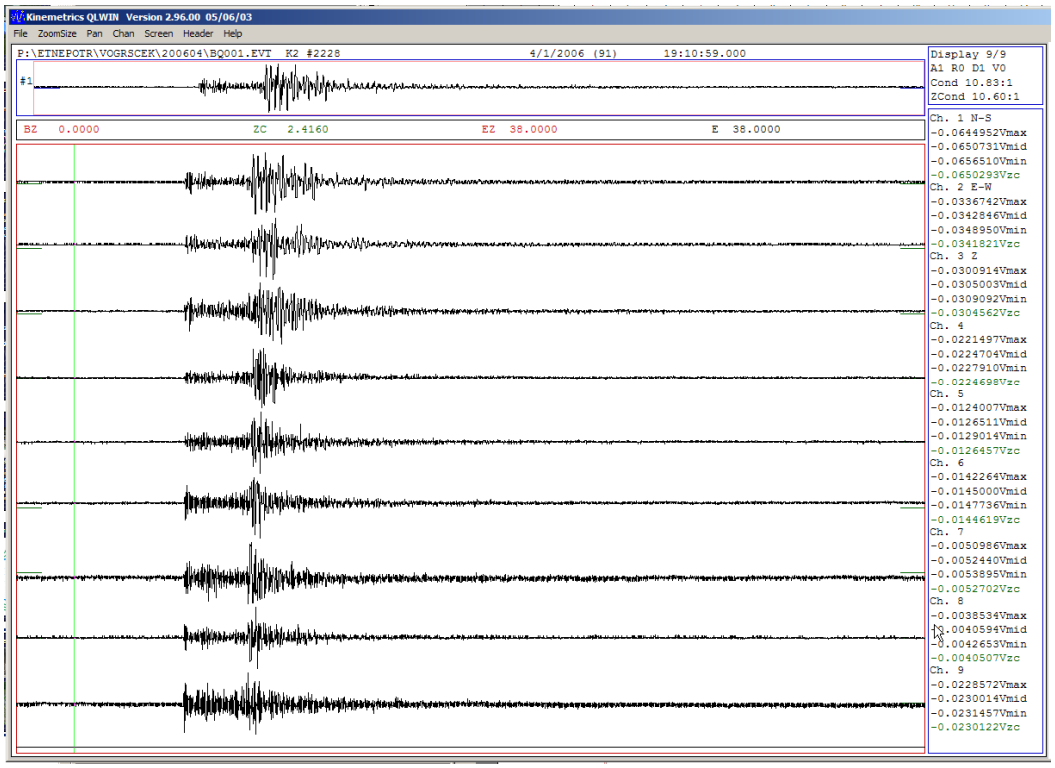
Slika 4 Centralna enota K2 z vgrajenim akcelerometrom je nameščena v jašku na kroni pregrade

V centralno enoto, ki je nameščena in z vijakom pritrjena na betonsko podlago v jašku na kroni pregrade, je vgrajen eden od treh akcelerometrov (slika 4). Druga dva sta nameščena in z vijakom pritrjena na betonski podlagi v jašku ob peti pregrade in v jašku za namestitev instrumenta na prostem površju. Pritrditev instrumentov na podlago zagotavlja stik senzorja s podlago tudi pri največjih pričakovanih pospeških. Pri montaži akcelerometrov je potrebno zagotoviti zavarovanje instrumentov pred mehanskimi poškodbami, ozemljitev in protistrelno zaščito. Vsi instrumeti na pregradi imajo enake lege smeri osi v prostoru,

Orientacija vsakega trikomponentnega instrumenta na pregradi mora biti taka, da je eden horizontalni senzor nameščen vzporedno s pregrado, drugi pa pravokotno na pregrado. Senzorji pospeška na prostem površju morajo biti orientirani v skladu s seizmološko prakso: vertikalni (Z), sever-jug (S-J) in vzhod-zahod (V-Z). Upoštevati je treba topografski sever.

Do centralne enote je napeljana klicna telefonska linija, po kateri poteka komunikacija s središčem za obdelavo podatkov Urada za seizmologijo in geologijo pri Agenciji RS za okolje.

Sistem je bil nameščen in vključen v obratovanje 1. junija 2004 vendar brez enega akcelerometra, ker jašek v peti pregrade ni bil vodotesen ter so bila potrebna dodatna gradbena dela. Zadnji akcelerograf je bil nameščen 20. oktobra 2005.



Slika 5 Zapis potresa z magnitudo 2,0, ki je nastal 1. aprila 2006 ob 19 uri in11 minut po UTC z nadžariščem v Grgarskih Ravnah

5. ZAKLJUČEK

Začetki posodobitve seizmičnega opazovanja segajo v leto 2000, do končne realizacije pa je bilo potrebno precej časa, nekaj zaradi časa, potrebnega za zagotovitev finančnih sredstev, nekaj pa tudi zaradi napak pri gradnji in naročanju opreme. V času delovanja novih instrumentov je bilo zabeleženih 6 potresov (slika 5).

6. REFERENCE

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