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OPTIMIZATION OF WAVES FLOW ON SLOPES IN VIEW OF THE PROBLEMATIC HYDROELECTRIC ENERGY CONVERSION

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ABSTRACT

In this paper it shows two-dimensional unsteady flow modeling with free surface wave which climbs and descends over a curved slope. Comparative analysis is made with two slopes, one straight, with $\alpha = 36^0$, another circular slope, with R=650 m. Study ends with the visualization of distribution of velocities and pressures for all three types of slopes. It shows the propagation speed and pressure in the field for the parabolic slope $\alpha = 2.5^0$, considering that in a first phase as there is no deformation of free surface; the presentation was done for the times:T=0.01s; T=0.25s; T=0.50s; T=1.00s; T=1.50s; then it shows the variation of the speed and pressure at times: T=0.01s; T=0.25s; T=0.50s; T=0.75s; T=1.00s, considering the surface wave for comply with $\lambda = 0.4$ m on the same slope, then circular slope with R= 650 m and on straight slope with tilt $\alpha = 36^0$. The presentation was done with SMS (Surface Modeling System), which support as input speed values in the points (x,y) of color curves and generates velocity v=ct., and pressure p=ct., or displays in vectorial template.

Keywords*: *Flow, Modeling, Optimization, Slope,Wave

I. INTRODUCTION

Procedures for measurement of waves parameters can be based on methods with contact (water) and non-contact methods [1]. The waves are rhythmic movements of the particles of water around an imaginary point of balance [2]. Sea currents which can be presented in the different forms of:horizontal currents (due to dominant winds); vertical currents (or ascends/descends from the waters to depths); marine water currents (due to planetary movement), are carries of some particulary large kinetic energies.

The waves have potential energy, kinetic energy, E_p and E_c and they are calculated according to the size of the elements and wave speed [3].

In this paper the flow is considering like a two-dimensional unsteady flow with free surface wave which climbs and descends over a curved slope.

II. THE EQUATIONS OF MOTION AND CONTINUITY EQUATION

We analized the equations of movement in two dimensions attached to the point from the slope (equation (1) and equation (2)):

$$U'_T + U\,U'_X + V\,U'_Y + \frac{1}{\rho}P'_X = -g\,\sin\alpha \qquad (1)$$

$$V'_T + U\,V'_X + V\,V'_Y + \frac{1}{\rho}P'_Y = -g\,\cos\alpha \qquad (2)$$

The continuity equation is equation (3):

$$U'_X + V'_Y = 0 \cdot \qquad (3)$$

It is necessary to remove the pressure because its value isn't known on the solid boundary and the distribution is unknown within our domain. For this, we derivate the equation (1) related to Y and (2) related to X, subtraction the equation (2) from equation (1) and obtain the equation (4) of motion which becomes when we consider the irotational expression, equation (5):

$$U''_{YT} - V''_{XT} + U'_X\left(U'_Y - V'_X\right) + U\left(U''_{XY} - V''_{XX}\right) + V'_Y\left(U'_Y - V'_X\right) + V\left(U''_{YY} - V''_{XY}\right) + g\alpha'_X\sin\alpha = 0 \qquad (4)$$

$$U''_{YT} - V''_{XT} + U\left(U''_{XY} - V''_{XX}\right) + V\left(U''_{YY} - V''_{XY}\right) + g\alpha'_X\sin\alpha = 0 \qquad (5)$$

Because must the solution to win in generality and the shape of studied domain must to be simplified, the equations of system will be undimensionalized. For this, we choose like characteristical measurements: static level (Y_{st}=H_0 =ct) for x≤0; the level of the free surface of the traveler wave (Y_0 (x,T));T_0 =ct-the period of the wave;the propagation wave speed (c_0 =ct);the atmospherical pressure on the free surface of wave (p_0 =ct) (Fig.1 and Fig. 2).

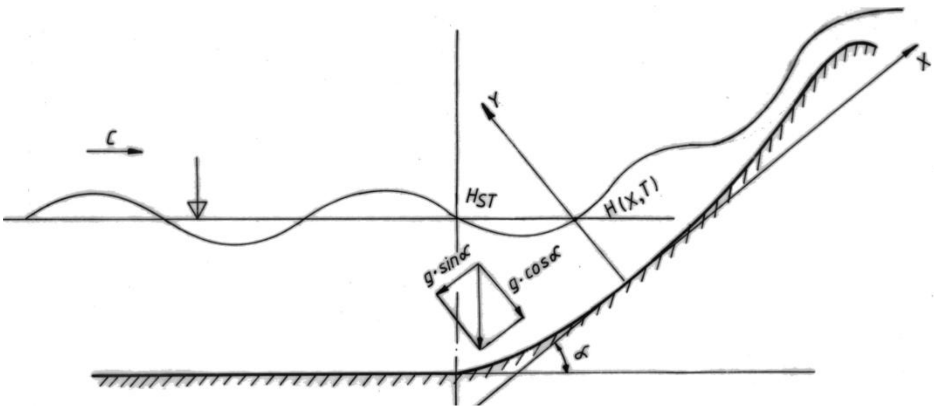

Fig. 1. The Study Domain

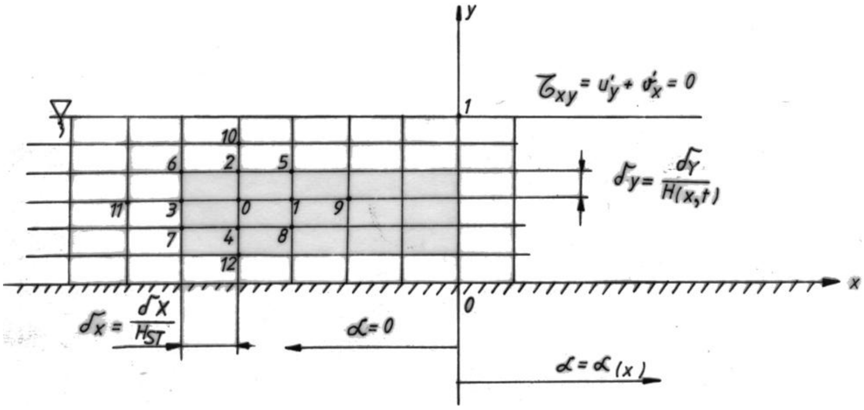

Fig. 2. The study domain after un dimension

The connection between old and new variables (equation (6)) and the undimensional functions (equation (7)) are presented below:

$$x = X/Y_{ST}, \qquad y = Y/Y_0(X,T), \qquad t = T/T_0, \tag{6}$$

$$u = \frac{U}{c_0}, \qquad v = \frac{V}{c_0}, \qquad \psi(x,y,t) = \frac{\Psi(X,Y,T)}{c_0\left[Y_0(X,T) - Y_{ST}\right]} \tag{7}$$

We calculate the derivates for undimensional coordinates (equation (8)):

$$x'_X = \frac{1}{Y_{ST}} \qquad x'_Y = 0 \qquad x'_T = 0$$

$$y'_X = \frac{-Y\,Y'_{0X}}{Y_0^2} = -\frac{y\,Y'_{0X}}{Y_0} \qquad y'_Y = \frac{1}{Y_0} \qquad y'_T = \frac{-Y\,Y'_{0T}}{Y_0^2} = -\frac{y\,Y'_{0T}}{Y_0} \tag{8}$$

$$t'_X = 0 \qquad t'_Y = 0 \qquad t'_T = \frac{1}{T_0}$$

and after this, we calculate, separately, each term of equation of motion (equation (9)). So:

$$U'_Y = c_0\,u'_Y = \frac{c_0}{Y_0}u'_y$$

$$U''_{YT} = c_0\frac{(u'_y)'_T\,Y_0 - Y'_{0T}u'_y}{Y_0^2} = \frac{c_0}{Y_0^2}\left(-\frac{y\,Y'_{0T}}{Y_0}Y_0\,u''_{yy} + \frac{Y_0}{T_0}u''_{yt} - Y'_{0T}u'_y\right) =$$

$$= \frac{c_0}{Y_0}\left(-\frac{y\,Y'_{0T}}{Y_0}u''_{yy} + \frac{1}{T_0}u''_{yt} - \frac{Y'_{0T}}{Y_0}u'_y\right)$$

$$V'_X = c_0\,v'_X = c_0\left(v'_x\frac{1}{Y_{ST}} - v'_y\frac{y\,Y'_{0X}}{Y_0}\right) \tag{9}$$

Finaly we can write the undimensional equation (10):

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$$c_0\left(-\frac{y\,Y'_{0T}}{Y_0^2}u''_{yy}+\frac{1}{T_0Y_0}u''_{yt}-\frac{Y'_{0T}}{Y_0^2}u'_y\right)-$$

$$-c_0\left(-\frac{y\,Y'_{0T}}{Y_0Y_{ST}}v''_{xy}+\frac{1}{T_0Y_{ST}}v''_{xt}+\frac{y^2Y'_{0T}Y'_{0x}}{Y_0^2}v''_{yy}+2\frac{y\,Y'_{0T}Y'_{0x}}{Y_0^2}v'_y-\frac{y\,Y'_{0x}}{Y_0T_0}v''_{yt}-\frac{y\,Y''_{0xT}}{Y_0}v'_y\right)+$$

$$+c_0^2u\left(\frac{1}{Y_0Y_{ST}}u''_{xy}-\frac{Y'_{0x}}{Y_0^2}u'_y-\frac{Y'_{0x}y}{Y_0^2}u''_{yy}\right)+$$

$$+c_0^2u\left(-\frac{1}{Y_{ST}^2}v''_{xx}+2\frac{y\,Y'_{0x}}{Y_0Y_{ST}}v''_{xy}+\frac{y\,Y''_{0xx}}{Y_0}v'_y-2\frac{Y'^2_{0x}}{Y_0^2}y\,v'_y-\frac{Y'^2_{0x}y^2}{Y_0^2}v''_{yy}\right)$$

$$+c_0^2v\left(\frac{1}{Y_0^2}u''_{yy}-\frac{1}{Y_{ST}Y_0}v''_{xy}+\frac{y\,Y'_{0x}}{Y_0^2}v''_{yy}+\frac{Y'_{0x}}{Y_0^2}v'_y\right)+\frac{1}{c_0}g\alpha'_x(x)\sin\alpha(x)=0 \tag{10}$$

The undimensional continuity equation is (equation 11):

$$\frac{Y_0}{Y_{ST}}u'_x-y\,Y'_{0x}u'_y+v'_y=0\cdot \tag{11}$$

To resolve the equations (10) and equation (11) we have used the uni-passTaylor method (the development of the Taylor series of the solution the equation around point x_0). We write the derivate of some function f(x,y) according to its values in neighboring points, replace the expressions of the derivates in the diferential equation and get equation (12):

$$\frac{2y\,Y'_{0T}}{Y_0^2b^2}u_0+\frac{2y^2Y'_{0T}Y'_{0x}}{Y_0^2b^2}v_0+\frac{c_0}{Y_0Y_{ST}}\frac{u_5+u_7-u_6-u_8}{4ab}u_0-\frac{c_0Y'_{0x}}{Y_0^2}\frac{u_2-u_4}{2b}u_0-$$

$$-\frac{c_0y\,Y'_{0x}}{Y_0^2}\frac{u_2+u_4}{b^2}u_0+2\frac{c_0y\,Y'_{0x}}{Y_0^2b^2}u_0^2-\frac{c_0}{Y_{ST}^2}\frac{v_1+v_3}{a^2}u_0+2\frac{c_0}{Y_{ST}^2a^2}v_0u_0+$$

$$+\frac{c_0y\,Y'_{0x}}{2Y_{ST}Y_0}\frac{v_5+v_7-v_6-v_8}{ab}u_0+\frac{c_0y\,Y''_{0xx}}{Y_0}\frac{v_2-v_4}{2b}u_0-\frac{c_0y\,Y'^2_{0x}}{Y_0^2}\frac{v_2-v_4}{b}u_0-$$

$$-\frac{c_0y^2Y'^2_{0x}}{Y_0^2}\frac{v_2+v_4}{b^2}u_0+\frac{2c_0y^2Y'^2_{0x}}{Y_0^2b^2}v_0u_0+\frac{c_0}{Y_0^2}\frac{u_2+u_4}{b^2}v_0-\frac{2c_0}{Y_0^2b^2}u_0v_0-$$

$$-\frac{c_0}{Y_{ST}Y_0}\frac{v_5+v_7-v_6-v_8}{4ab}v_0+\frac{c_0y\,Y'_{0x}}{Y_0^2}\frac{v_2+v_4}{b^2}v_0-\frac{2c_0y\,Y'_{0x}}{Y_0^2b^2}v_0^2+\frac{c_0Y'_{0x}}{Y_0^2}\frac{v_2-v_4}{2b}v_0-$$

$$-\frac{y\,Y'_{0T}}{Y_0^2}\frac{u_2+u_4}{b^2}+\frac{\left[(u_2-u_4)-(\bar{u}_2-\bar{u}_4)\right]}{2bcT_0Y_0}-\frac{Y'_{0T}}{Y_0^2}\frac{u_2-u_4}{2b}+\frac{y\,Y'_{0T}}{Y_0Y_{ST}}\frac{v_5+v_7-v_6-v_8}{4ab}-$$

$$-\frac{\left[(v_1-v_3)-(\bar{v}_1-\bar{v}_3)\right]}{2acT_0Y_{ST}}-\frac{y^2Y'_{0T}Y'_{0x}}{Y_0^2}\frac{v_2+v_4}{b^2}-\frac{y\,Y'_{0T}Y'_{0x}}{Y_0^2}\frac{v_2-v_4}{b}+$$

$$+\frac{y\,Y'_{0x}}{2bcY_0T_0}\left[(v_2-v_4)-(\bar{v}_2-\bar{v}_4)\right]+\frac{y\,Y''_{0xT}}{2Y_0}\frac{v_2-v_4}{b}+\frac{1}{c_0}g\alpha'_x\sin\alpha(x)=0 \tag{12}$$

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The associated equation for continuity equation is equation (13) from which can obtain u:f (u_0 , u_2) and from the equation of motion (12) we can obtain v[Ca, Pa]:

$$\frac{Y_0}{Y_{ST}}\frac{u_1-u_0}{a}=y\,Y'_{0x}\frac{u_2-u_0}{b}+\frac{v_2-v_0}{b}\cdot \qquad (13)$$

III. THE RESULTS AND INTERPRETATIONS

We modelated numerically flow on slope using a computing program whose organizational structure is presented in the Fig. 3 and Fig. 4.

The program of calculus considering:

1. The study area is the zone $\alpha \geq 0$, and according to Fig. 1 and Fig. 2; at the initial time there isn't movement in this area, so the starting hollow speeds;
2. The second step is to calculate the value of the classical theory of speed undersinusoidal wave (Gerstner);
3. On the basis of these speeds are calculated by finite differences method to modify the values for the next step;
4. Compare with baseline, and if the error in a single point on a column exceedsthe prescribed (10-8), then resumes calculation considering that the initial new values obtained;
5. After getting the relaxation on the proceed to next column; If the speeds are very low or if it touches the x-axis corresponding to the results, proceed to thenext step (step time dimensional was taken so as to instantly network points so ,$^{\delta}t = {}^{\delta}x/C_0$ =1 cm/0.7 m/s`0.014 s).

Basis of the program have studied several types of slopes:

-Straight, slanted at the angle $\alpha = 25^0 \ldots 40^0$;

-Circular rays "R = 500 mm ... 700 mm;

-Parabolic-slope "with continuous increment of angle α between $1^0 \ldots 3.5^0$.

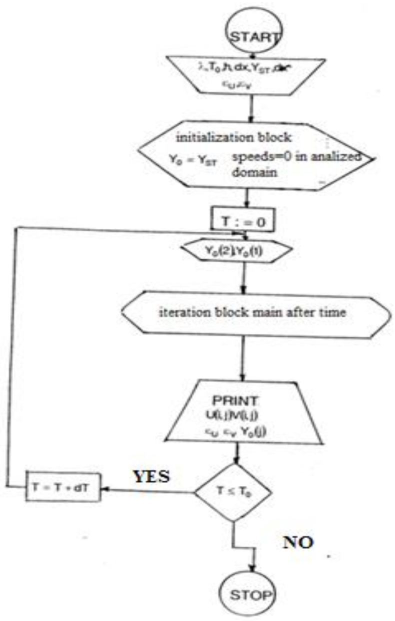

Fig. 3. The Organizational Structure

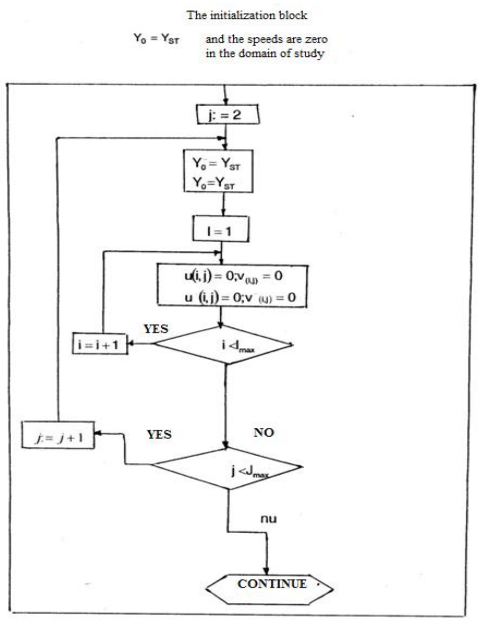

Fig. 4. The Initialization Block

For each slope was obtained by flow discharged Q [cm^3/s m], by integrating field speeds in 17 points of the column in the area of the top of slope. Wave parameters studied were those who fit the wave "study" chosen as optimal for romanian coastal beach λ = 13.7 m, h = 0.5 m, which corresponds to the same $Sh^{-1} = \lambda/h = 17.0$ laboratory values λ = 0.7 m, T = 1 s, C_0 = 0.4 m/s. The obtained values are presented in TABLE 1 for straight slope, TABLE 2 for circular slope and TABLE 3 for parabolic slope:

TABLE 1. The values for straight slope.

α [degree]	25	30	35	40
Q_{dev} [cm^3 /s m]	107	130	181	172

TABLE 2. The values for circular slope.

R [cm]	500	550	600	650	700
Q_{dev} [cm^3 /s m]	107	130	181	172	240

TABLE 3. The values for parabolic slope.

α [degree]	1	2	2.5	3	3.5
Q_{dev} [cm^3 /s m]	100	215	252	218	210

The dimensions of studied slopes are presented in the Fig.3, Fig. 4 and Fig. 5:

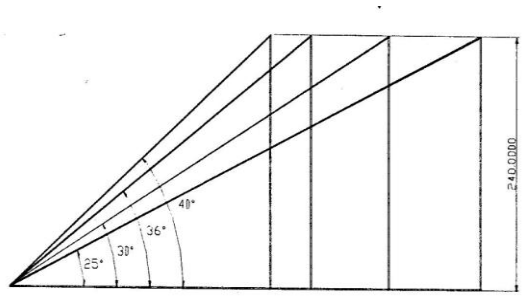

Fig. 4. The straight slope

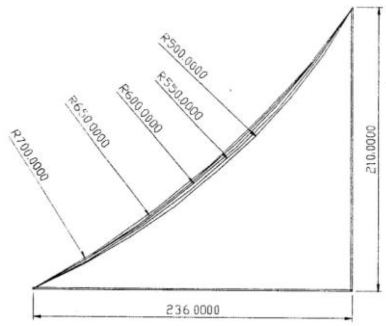

Fig. 5. The circular slope

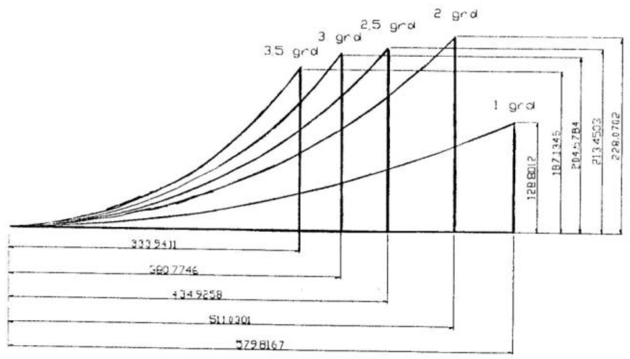

Fig. 6. The parabolic slope

In the Fig. 7.....Fig.30 we present the propagation of speed and pressure on the parabolic slope with α=2.5^0; first we consider without deformation of the free surface:

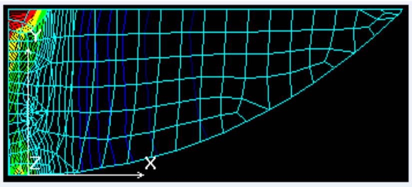
Fig. 7. Speed at T=0.01 s

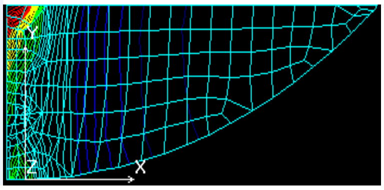
Fig. 8. Speed at Speed at T=0.01 s

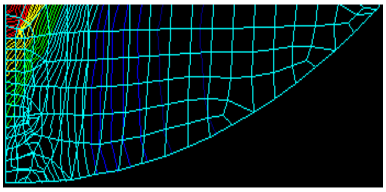
Fig. 9. Speed at T =0.25 s

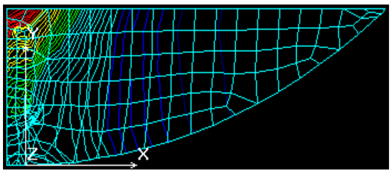
Fig. 10. Speed at T =0.50 s

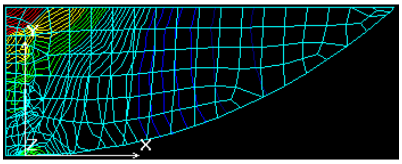
Fig. 11. Speed at T =1.00s

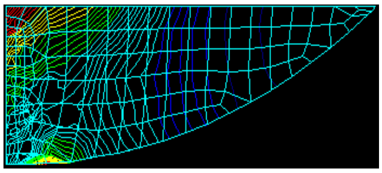
Fig. 12. Speed at T =1.50 s

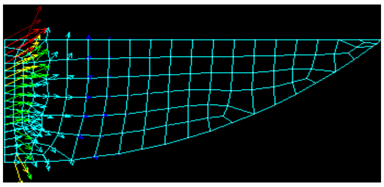
Fig. 13. Speed at T =0.01 s

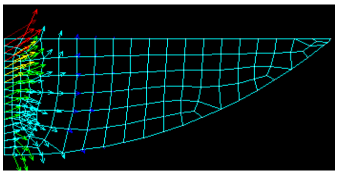
Fig. 14. Speed at T =0.05 s

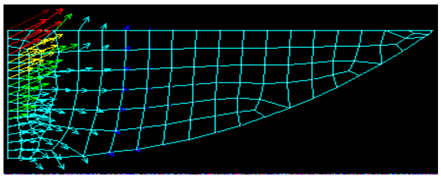
Fig. 15. Speed at T =0.25 s

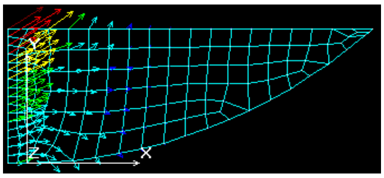
Fig. 16. Speed at T =0.50s

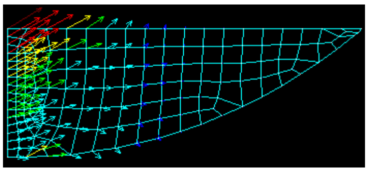
Fig. 17. Speed at T =1.00 s

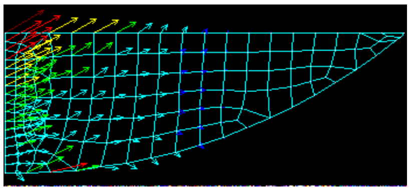
Fig. 18. Speed at T =1.50 s

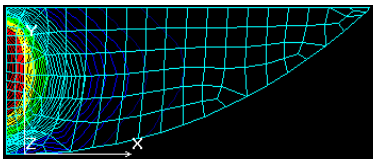
Fig. 19. Pressure at T =0.01 s

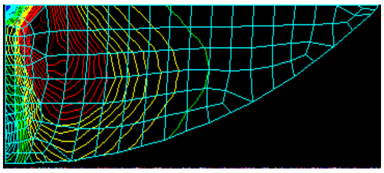
Fig. 20. Pressure at T =0.05 s

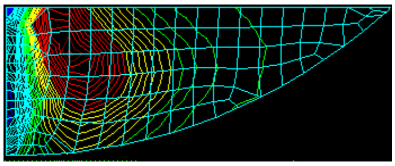
Fig. 21. Pressure at T =0.25 s

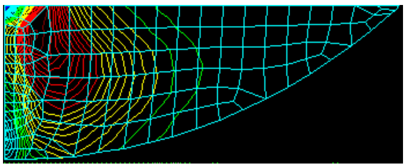
Fig. 22. Pressure at T =0.50 s

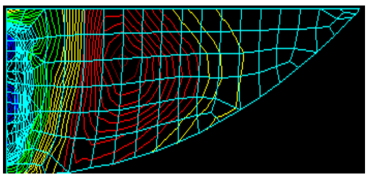
Fig. 23. Pressure at T =1.00 s

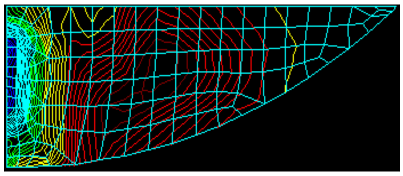
Fig. 24. Pressure at T =1.50 s

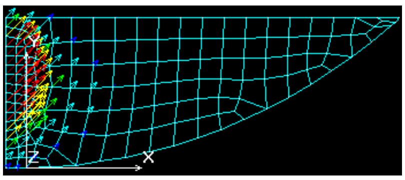
Fig. 25 Pressure at T =0.01 s

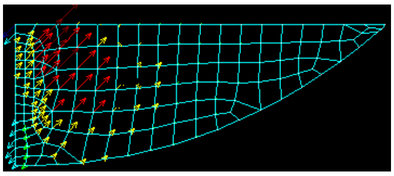
Fig. 26. Pressure at T = 0.05 s

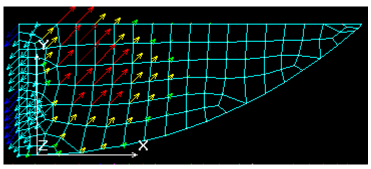
Fig. 27. Pressure at T =0.25 s

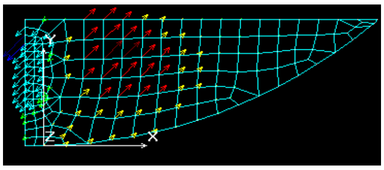
Fig. 28. Pressure at T =0.50 s

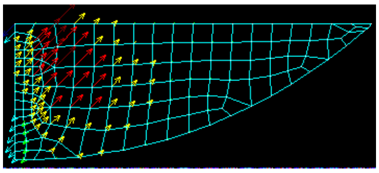
Fig. 29. Pressure at T =1.00 s

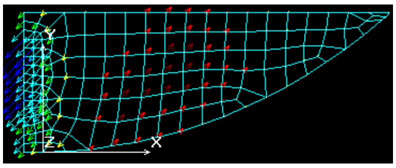
Fig. 30. Pressure at T =1.50 s

In the Fig. 31...Fig. 45 we present the propagation speed and pressure for parabolic slope but with surface corresponding to wave with λ=0.7 m:

Parabolic slope –surface corresponding to wave with λ=0.7 m

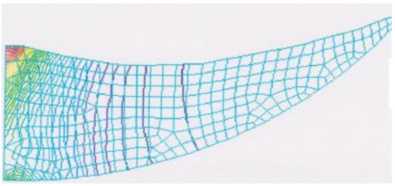
Fig. 31. Speed at T = 0.01 s

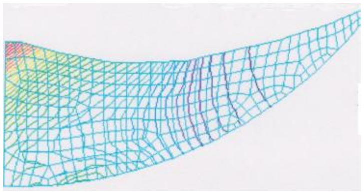
Fig. 32. Speed at T = 0.25 s

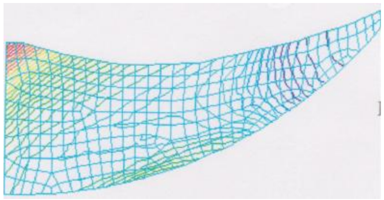
Fig. 33. Speed at T = 0.50 s

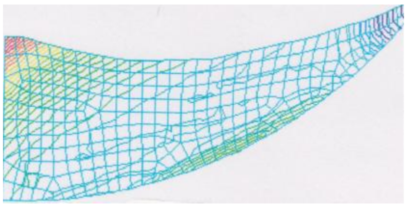
Fig. 34. Speed at T = 0.75 s

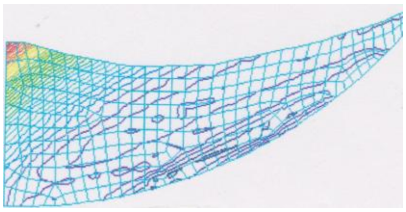
Fig. 35. Speed at T = 1.00s

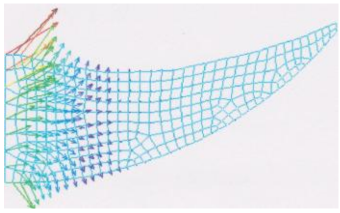
Fig. 36. Speed at T = 0.01 s

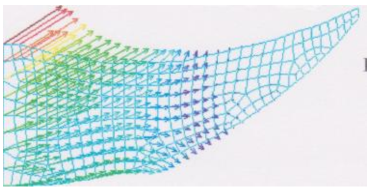
Fig. 37. Speed at T = 0.25 s

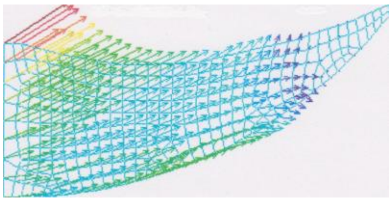
Fig. 38. Speed at T = 0.50 s

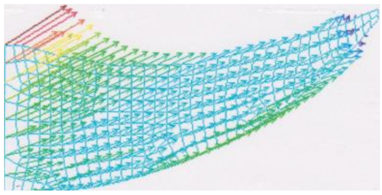
Fig. 39. Speed at T = 0.75 s

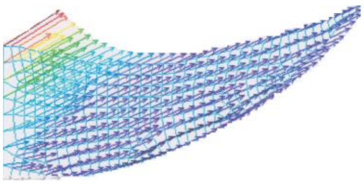
Fig. 40. Speed at T = 1.00 s

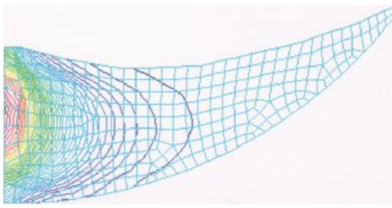
Fig. 41. Pressure at T = 0.01 s

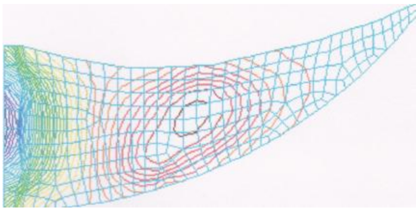
Fig. 42. Pressure at T = 0.25 s

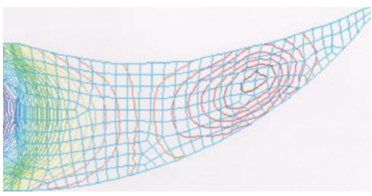
Fig. 43. Pressure at T = 0.50 s

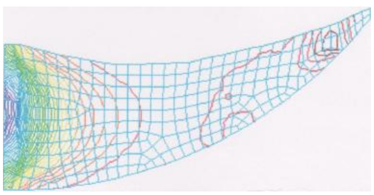
Fig. 44. Pressure at T = 0.75 s

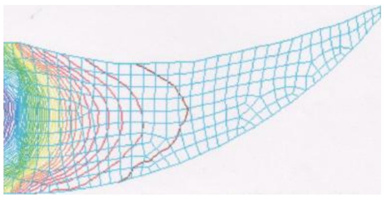
Fig. 45. Pressure at T = 1.00 s

In the Fig. 46...60 we present the circular slope with R =650 m:

The circular slope with R = 650m

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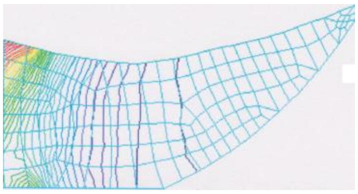
Fig.46. Speed at T = 0.01 s

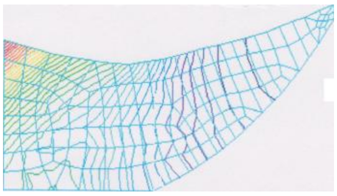
Fig. 47. Speed at T = 0.25 s

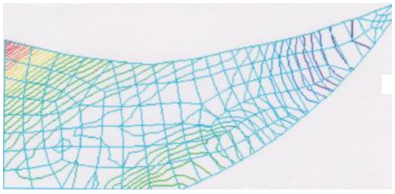
Fig. 48. Speed at T = 0.50 s

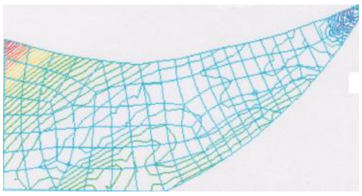
Fig.49. Speed at T = 0.75 s

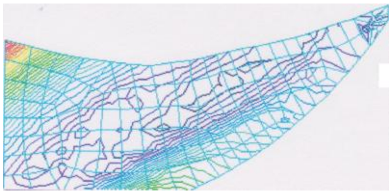
Fig. 50. Speed at T = 1.00 s

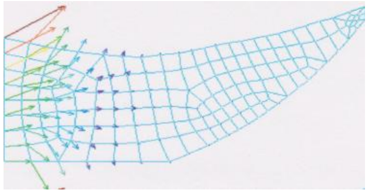
Fig. 51. Speed at T = 0.01 s

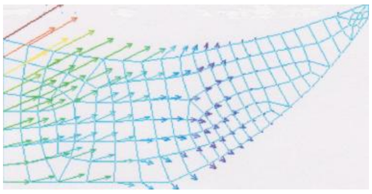
Fig.52. Speed at T = 0.25 s

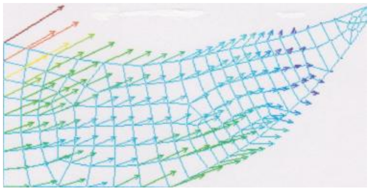
Fig. 53. Speed at T = 0.50 s

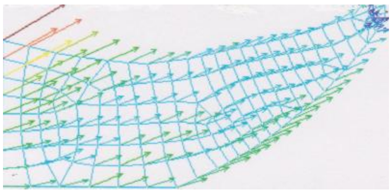
Fig. 54. Speed at T = 0.75 s

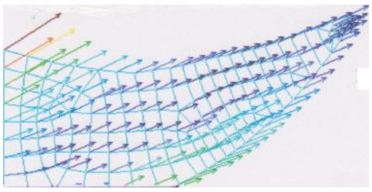
Fig. 55. Speed at T = 1.00 s

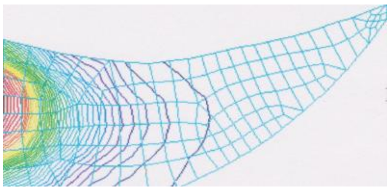
Fig. 56. Pressure at T = 0.01 s

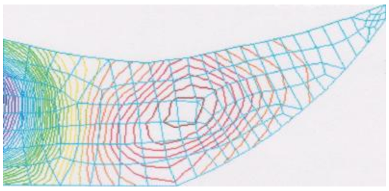
Fig. 57. Pressure at T = 0.25 s

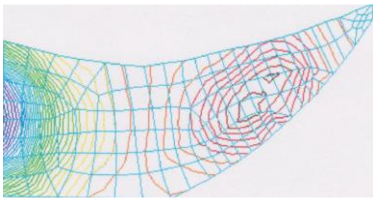
Fig. 58. Pressure at T = 0.50 s

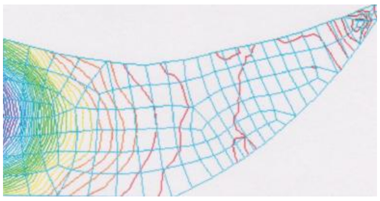
Fig. 59. Pressure at T = 0.75 s

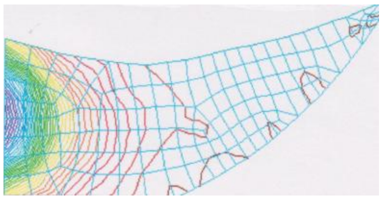
Fig. 60. Pressure at T = 1.00 s

In the Fig. 61...74 we present the straight slope with tilt $\alpha=36^0$:

The straight slope with tilt $\alpha = 36^0$

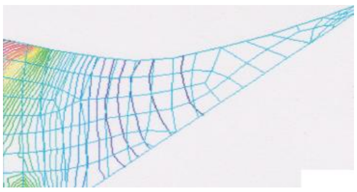
Fig. 61. Speed at T = 0.01 s

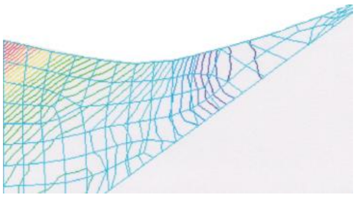
Fig. 62. Speed at T = 0.25 s

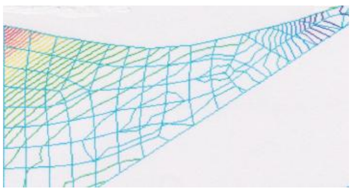
Fig. 63. Speed at T = 0.50 s

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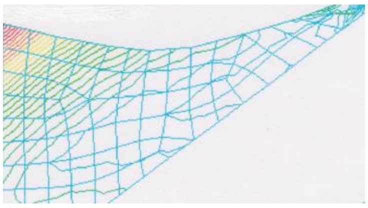
Fig. 64. Speed at T = 0.75 s

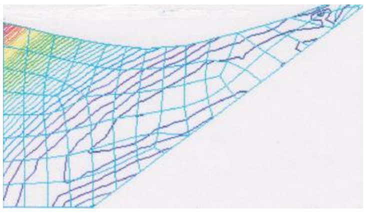
Fig. 65. Speed at T = 1.00 s

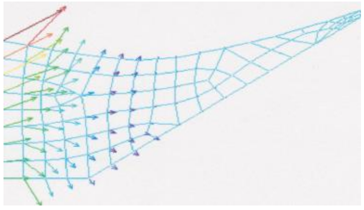
Fig. 66. Speed at T = 0.01 s

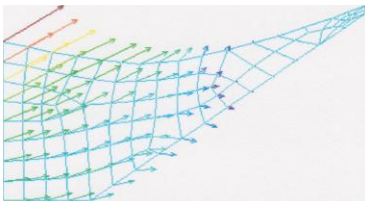
Fig. 67. Speed at T = 0.25 s

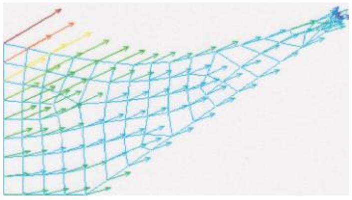
Fig. 68. Speed at T = 0.75 s

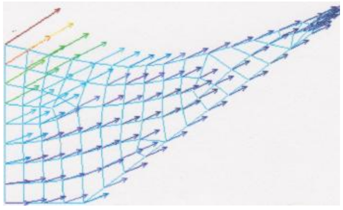
Fig. 69. Speed at T = 1.00 s

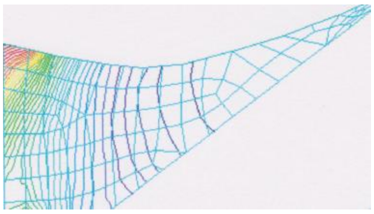
Fig. 70. Pressure at T = 0.01 s

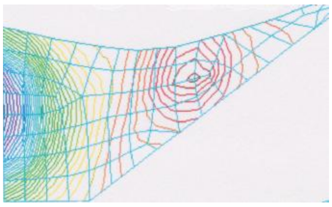
Fig. 71. Pressure at T = 0.25 s

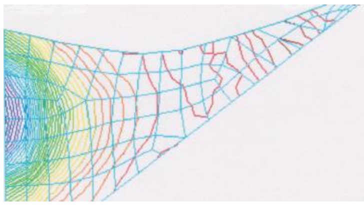
Fig. 72. Pressure at T = 0.50 s

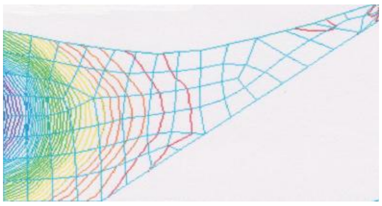
Fig. 73. Pressure at T = 0.75 s

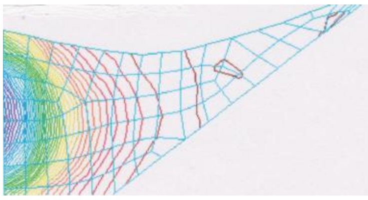
Fig. 74. Pressure at T = 1.00 s

Finally, we obtained the resultant of speeds (Fig. 75) and the resultant of pressures (Fig. 76).

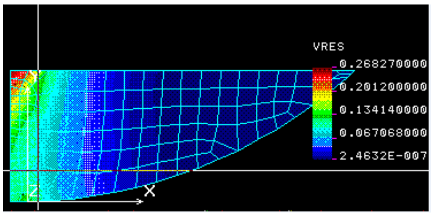

Fig. 75. The resultant of speeds

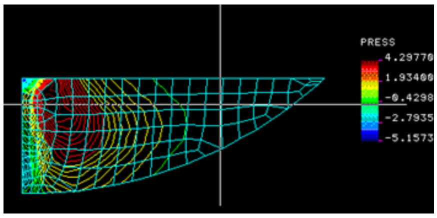

Fig. 76. The resultant of pressures

IV. CONCLUSION

The advantage of the method is that substitutes for field of study whose height is available in space in time with a rectangular network of constant height throught a convenient undimension.

The best slope is one who has the greatest velocities on the ridge and dumping blade width, so the highest flowrate (Q_{dev} = v.S) [3].

Numerical calculation method presented must be validated by experiment [1], [4]. We have experimented these types of slopes in the laboratory [3] and after this, we have compared the numerical data with experimental data.

The conclusion is: the best slope is the parabolic slope (Q_{dev}=252 cm^3 /s.m, for α $_=$2.5^0), which suggest for applications on the romanian coastal beach.

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