Recyclable Belt Conveyors Used to Prevent and to Decrease the Flood Effects

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Abstract: -The European Union promotes new products using recyclable and biodegradable raw materials, low consuming energy and no pollution in the environment at the life-time end cycle.
A new method of environment protection against floods proposes modular drains and dykes made by recoverable and recyclable belt conveyors materials. These recoverable materials are at their life-time end; therefore it is necessary to study the mechanical characteristics of recyclable belt conveyors materials to establish the parameters that have to be respected for making modular panels with good static and dynamic stability.
The paper presents the mechanical characteristics data of recyclable belt conveyors, used for elastic deformation simulation calculated with an analytical method.

Key-Words: - Modular Drains/Dykes, Recyclable Materials

1. Introduction

In the European Union all designing activities have to respect for the following recommendations: the decrease of natural resources utilization; choosing of ecological materials; to promote new-tech elements in process designing; new standards of the quality of designing process; study of durability; recyclable products utilizing; estimation of the acceptance degree; making study of consequences. [2, 3, 6]

The environment's protection programme in the European Union permits to define the main directions of the policy of environment's protection and economical development in all activities in industry, energy, transport, agriculture and tourism.

The legislation which was elaborated and will be elaborated insists on more rational using of resource for a higher efficiency in their capitalization.

The recycling of products, become an important objective of the sustainable resources conservation.

The management of the waste materials relies on two principles: to avoid the waste materials accumulating, and to recover and to recycle all the industrial materials. The waste materials which are not able to be recycled for capitalization, have to be eliminated with efficient and safety methods.

In the last years, more and more researchers are interested in finding new methods to reduce the floods effects. [2, 7]

The assessment schema of the impact produced by hydrotechnical improvement on environment can be used for any other kind of particular scheme, being determined by the correctness establishment of specific and ecological effects. Depending on their size, and on their importance, the necessary results for the assessment of the impact are obtained.

On this basis, we can make the suitable decisions; we can rectify the different kinds of influences or make correct analysis respecting the conclusions and the results obtained by the experts.

The methodology can be used when we have an informational system and a data bank suitable for the value of each action's effect. The concept of sustainable development has been appropriate by UNO which has recommended national programmes and strategies of the environment protection. [3, 4, 7]

The study of floods effects decrease, using modular drains and dykes made by recyclable materials from recoverable belt conveyors was a research project financed by the Romanian Ministry for Education and Research. [4]

In Romania, the current methods for floods prevention have in view two main types of actions:

- consolidation activities made as preventive works or made at the imminence of floods, activities done with construction heavy equipment;
- minimum stocks of sand sacks made by the local authorities; the measure of these stocks and their location in zones where the floods danger could appear, is made by IJPCSU (Departmental Civil Protection Inspection and Urgent Situations) and CNAR (Romanian Water National Company).

There are also known technological supplementary methods which recommend the application of some polyethylene thin sheets over the sand sacks in order to improve the water- tightness for all the dyke height.

These two methods have also inconvenience caused by the of transporting and using heavy equipment possibilities, in very short times in rough country, and also caused by the great quantity of sand sacks and human effort for achievement the increase of the dyke height.

The specialty literature shows that the reduction of the risk can be realized only by an integrated system of measures.

In the economic and social context of Romania, the sphere approached by this project is found in the priorities of scientific research and innovation plan concerning in new measures and methods of the environment's protection, in new technologies of recovery and recycling of the materials which are at the end of their using life, and also for new jobs appearing after the turning to account of researches' results by technological transfer to small and middle enterprises.

New jobs could be created, especially in unprosperous areas from the mining fields where small and middle enterprises could be organized, which recovery and recycling belt conveyors to get new products that should rely on the technological transfer.

Recovery and recycling of raw material and of materials at the end of their using life represent strategically priorities, both in the national research-development programmes, and in the research programmes financed by the European Union.

The new proposed method concerns in the recovery and recycling of rubber belt conveyors with an expired using life, conveyors which are still in traditional user propriety, from mining or metallurgy industries.

In the Romanian National Lignite Company is using more then 500 km belt conveyors with textile insertions PES/PA type (polyester/polyamide), CV/PA type (viscose/polyamide) and with steel cord (ST type) conveyor belts.

These belt conveyors categories are characterized by the main parameters: the belt tensile strength *250 – 4000 N/mm*; the belt thickness *10 - 25 mm*; the approximate mass *12 – 30* kg/m^2.

It must be specified that during working-time the belts might be repaired in special workshops, but the durability of these belts is *20-30%* smaller than the new belts. [4, 6]

The recoverable belt conveyors materials are at the end-life duty, therefore the real mechanical characteristics are necessary to be known for making modular panels with good static and dynamic stability.

2. Experimental Method Considerations

To determine the recovering and recycling possibilities for end-life belt conveyors materials, samples of steel cable insertion (ST) conveyor belts, with *40 - 50%* rate of wear, were tested in order to establish the longitudinal tensile strength of the belts and the specific pulled out strength steel cable according to STAS 10674-96. [4, 6]

In Table 1 and Table 2 are presented the recommended data in standard 10674-96, and the experimental data obtained for representative used ST belts. [4, 6]

Table 1

Strength category	Longitudinal tensile strength [N/mm]	
	Data in standard, for new belt	Experimental data, for used belt
ST 1250	1250	680
ST 1600	1600	960
ST 2000	2000	1240
ST 2500	2500	1620

Table 2

Strength category	Steel cable specific pulled out strength [N/mm]	
	Data in standard, for new belt	Experimental data, for used belt
ST 1250	70	40
ST 1600	85	55
ST 2000	85	60
ST 2500	100	70

The longitudinal tensile strength of the belt experimentally established for different ST belt types with different rate of wear, is *35 - 45%* smaller than recommended value according to product standard.

The steel cable specific pulled out strength experimentally established for different types of belts with the same wear rate, is *30 - 40%* smaller than recommended value according to the product standard.

A special interest is represented by the steel insertion belts with the ST 1250 - 2500 strength category, with *1000 - 1600mm* width and *16-25mm* thickness.

The specific weight of these belts recommends *2 - 2,5m* length size, belt segments size adopted from point of view of storage during the transport and manipulation assembly possibilities.

To determine the recovering and recycling possibilities for end-life belt conveyors materials, samples of belt conveyors with *40 - 50%* rate of wear, with textile insertions PES/PA type (polyester/ polyamide) and CV/PA type (viscose/ polyamide), were tested in order to establish the longitudinal and transversal tensile strength in the thickness of the belt according to Romanian standard (STAS 8915-98).

In Table 3 and Table 4 are presented the recommended values in STAS 8915-78, and the experimental data obtained for representative used belts with textile insertions PES/PA type (polyester/ polyamide), CV/PA type (viscose/polyamide). [4, 6]

Table 3

Strength category	Tensile strength in the thickness of the belt [N/mm]	
	Longitudinal	
	Data in standard, for new belt	Experimental data, for used belt
630	630	330
800	800	440
1000	1000	570
1250	1250	690

Table 4

Strength category	Tensile strength in the thickness of the belt [N/mm]	
	Transversal	
	Data in standard, for new belt	Experimental data, for used belt
630	190	110
800	250	140
1000	320	180
1250	380	210

Comparative with the recommended values in the product standard, the tensile strength on the thickness of the belt, experimentally determined for different types of belts with the same wear degree, can be *45-50%* smaller for the longitudinal charge tensile strength and can be *40-45%* smaller for the transversal charge tensile strength.

The experimental data obtained for the longitudinal tensile strength and for the steel cable specific pulled out strength of the end-life steel insertion belts, and the longitudinal and transversal tensile strength in the thickness of the textile insertions belts represent conformity criteria for the recovery and recycling materials method at the end-life belt conveyors.

3. Mathematical Model Considerations

The results of the experimental researches presented in the table 1÷4 permit calculation of the admissible efforts for the modular segments made by recoverable belt conveyors, taking in account the dynamic loads of the flood effects: flow, velocity, pressure.

3.1. Mathematical model for flood flow

The mathematical model used for establish the flood flow variation law, take into account the differential equation of non-permanent flow/motion of the fluids in open riverbed/sewer, described by the Saint-Venant equations [2, 4, 7]:

- *Continuity equation*:

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = 0 . \qquad (1)$$

For the rectangle cross section shape ($A=B\cdot h$), the equation (1), becomes:

$$\frac{\partial h}{\partial t} + h\frac{\partial u}{\partial x} + u\frac{\partial h}{\partial x} = 0 \ . \qquad (2)$$

- *Dynamic equation*:

$$S_f = S_x - \frac{\partial h}{\partial x} - \frac{u}{g}\frac{\partial u}{\partial x} - \frac{1}{g}\frac{\partial u}{\partial t} , \qquad (3)$$

where: u - longitudinal velocity of flow;
x - longitudinal coordinate;
h - water depth;
B - maximum cross section width of sewer
A - flow cross section;
Q - flood water flow;
S_x - longitudinal slope;
S_f - sliding friction slope;
g - acceleration of gravity;
t - time.

In equation (3), the second term represents the *kinematical wave* influence, the third term represents the *diffusion wave* influence, and the last one represents the *dynamic wave* influence.

The equations (1) and (2) set a non-permanent flow mathematical model in which the real solution of the system $Q = Q(x,t)$, needs the following conditions:

- Initial conditions

$$t = 0, \quad h = h(x), \quad Q = Q(x) , \qquad (4)$$

- Boundary conditions

$$x = 0, \quad Q_0 = Q_0(t) \ , \qquad (5)$$

$$x = l, \quad Q_l = Q_l(h_l) \ , \qquad (6)$$

where $Q_o(t)$ - first sector breaking;
$Q_l(h_l)$ - limn metric key in the downstream sector.

There are necessary some initial conditions: plane flood conditions with no friction (sliding friction slope $S_f = 0$); the rectangle cross section sewer is horizontal ($S_x = 0$) and contains h_a water depth in upstream sector and no water in the downstream sector.

In these conditions, the characteristic equation is:

$$x = 2t\sqrt{gh_m} - 3t\sqrt{gh} \ , \qquad (7)$$

The kinematical wave model concerns negligible inertial terms and the initial condition in which the longitudinal slope is equal with sliding friction slope ($S_f = S_x$).

Generally, the flow is given by the relation:

$$Q = K_r A R^m \sqrt{S_f} \ , \tag{8}$$

where K_r – non-uniformity strength coefficient;
R – hydraulic radius;
m – empiric exponent.

In the permanent flow / motion, the nominal flow is determined with relation:

$$Q = Q_N = K_r A R^m \sqrt{S_x} \ , \tag{9}$$

With the relations (8) and (9), is obtained the relation:

$$Q = Q_N \sqrt{S_f / S_x} \ . \tag{10}$$

The relation (10), introduced in relation (1) gives the kinematical wave model.

The propagation of kinematical wave is calculated with the relation:

$$\frac{\partial Q}{\partial t} + c\frac{\partial Q}{\partial x} = 0 \ , \tag{11}$$

where c is the velocity values for a cross flow section.

In the kinematical wave model, the inertial and the pressure terms are negligible (compared with the friction forces and the gravity force).

The kinematical waves are propagated in upstream sector with no attenuation, but the wave shape is modified depending the local velocity.

$$c = \frac{dQ}{dA} = \frac{1}{B}\frac{dQ}{dh} \ . \tag{12}$$

If the effects of the free level of water slope can not be ignored, the uniform transversal/cross and longitudinal profile is modifying in a non-uniformed profile, and the $\partial h / \partial x$ term can not be neglected.

The diffusion equation is:

$$\frac{\partial Q}{\partial t} + c\frac{\partial Q}{\partial x} = D\frac{\partial^2 Q}{\partial x^2} \ . \tag{13}$$

The left side of the equation (13) represents the kinematical wave equation, and the right side of the equation is taken into account the diffusion effect of the non-uniform profile of the water free level.

The diffusion coefficient, which simulates the wave attenuation in upstream sector, is given by the relation:

$$D = \frac{Q}{2BS_x} \ . \tag{14}$$

The diffusion coefficient shows that the kinematical wave model is applied for great values of riverbed/sewer slope or for large width sewer. For small values of the riverbed/sewer slope, the diffusion coefficient can not be negligible.

Generally, the complete dynamic model is recommended when:

$$S_x \geq \frac{30}{T_p}\sqrt{h_N / g} \ , \tag{15}$$

where: T_p - affluent flood hydrograph;
h_N - depth of water level in the permanent, uniform flow.

In the hydrologic concept, the flows propagation in a sewer can be described by the equations:

- *Continuity equation*

$$\frac{dV}{dt} = Q_a - Q_d \ , \tag{16}$$

- *Motion equation*

$$V = T[\alpha Q_a + (1-\alpha) Q_d] = TQ_d + T\alpha(Q_a - Q_d) \tag{17}$$

where: V - channel storage volume, considered at t moment;
Q_a - affluent inflow in the sector;
Q_d - affluent outflow in the sector;
T - propagation time of the flood wave barycenter on the considered sector;
α - accumulation coefficient.

Using derived of the second equation (17), and equalization of the first equation (16), knowing the values of α and T, it is obtained:

$$Q_d + L\frac{dQ_d}{dt} = Q_a - k\frac{dQ_a}{dt} \ , \tag{18}$$

where $k = \alpha \cdot T$; $L = 1 - k$.

Using the notation:

$$Q_a - k\frac{dQ_a}{dt} = L\varphi(t) \ , \tag{19}$$

substituting in relation (18), it can be calculated Q_d with the equation:

$$\frac{Q_d}{L} + \frac{dQ_d}{dt} = \varphi(t) \ . \tag{20}$$

Before the flood (when time $t = 0$), there is a stationary flow, wherefore the solution of the flow equation is given by relation:

$$Q_d = e^{-t/L}\left[Q_0 - \int_0^t \varphi(0)dt + \int_0^t e^{-t/L}\varphi(t)dt\right]. \tag{21}$$

3.2. Mathematical model for elastic deformation of the belt segment

The analytical method for modeling elastic deformations of the recyclable belt segments starts from the water pressure variation law hypothesis [2, 4, 7]:

$$p = p_0(a + x)/2a \ , \tag{22}$$

where p_0 - the initial static water pressure;
a - length dimension of the segment belt;
x - current part of the main dimension a.

Starting from the real loading conditions, it can be determined the elastic deformation w of the belt segment, given in relation:

$$\frac{p}{D} = \frac{\partial^4 w}{\partial x^4} + 2\frac{\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4}\ , \qquad (23)$$

where y - axial variable which w is depending;
D - belt segment's rigidity under flood stress, calculated with relation:

$$D = \frac{Es^3}{12\left(1-\mu^2\right)}\ , \qquad (24)$$

where s - belt thickness;
μ - Poisson coefficient;
E - Young coefficient.

The particular solution of relation (22) is:

$$p_p = \frac{p_0}{48aD}(a+x)\left(y^4 - 6b^2y^2 + 5b^4\right), \qquad (25)$$

where a and b are the dimensions of the belt segment ($a > b$).

The elastic deformation w can be determined with the relation:

$$w = C(a+x)\left(y^4 - 6b^2y^2 + 5b^4\right) + \sum_{1,3,5..}^{\infty}\left[A_n ch\frac{\pi nx}{2b} + B_n sh\frac{\pi nx}{2b} + C_n x sh\frac{\pi nx}{2b} + D_n x ch\frac{\pi nx}{2b}\right]\cos\frac{\pi ny}{2b} \qquad (26)$$

where: $C = \dfrac{p_0\left(1-\mu^2\right)}{4aEs^3}$.

Imposing the initial conditions:

$$y = \pm b \quad \Rightarrow \quad |w|_{y=\pm b} = 0\,; \quad \left|\frac{\partial^2 w}{\partial y^2}\right|_{y=\pm b} = 0\,,$$

$$x = +a \quad \Rightarrow \quad |w|_{x=a} = 0\,; \quad \left|\frac{\partial^2 w}{\partial x^2}\right|_{x=a} = 0\,, \qquad (27)$$

and with serial development, results the equation:

$$A_n \cdot ch\frac{\pi na}{2b} + B_n \cdot sh\frac{\pi na}{2b} + 4C_n b\left(\frac{ch\frac{\pi na}{2b}}{\pi n} + \frac{a}{4b}\cdot sh\frac{\pi na}{2b}\right) + 4D_n b\left(\frac{sh\frac{\pi na}{2b}}{\pi n} + \frac{a}{4b}ch\frac{\pi na}{2b}\right) = 0 \qquad (28)$$

Eliminating A_n and B_n from (28) equations, it results:

$$-\frac{768Cab^3(-1)^{\frac{n+3}{2}}}{(\pi n)^4} + C_n a\cdot sh\frac{\pi na}{2b} + D_n a\cdot ch\frac{\pi na}{2b} = 0\,. \qquad (29)$$

For $x = a$, the bending forces and the resistance forces are both zero:

$$\frac{\partial^2 w}{\partial x^2} + \mu\frac{\partial^2 w}{\partial y^2} = 0\,, \qquad (30)$$

$$\frac{\partial^3 w}{\partial x^3} + (2-\mu)\frac{\partial^3 w}{\partial x \partial y^2} = 0\,. \qquad (31)$$

Due to (30) condition, results the equation:

$$A_n(1-\mu)\cdot ch\frac{\pi na}{2b} - B_n(1-\mu)\cdot sh\frac{\pi na}{2b} + 4C_n b\left(\frac{1}{\pi n}\cdot ch\frac{\pi na}{2b} + \frac{a}{4b}(1-\mu)\cdot sh\frac{\pi na}{2b}\right) + 4D_n b\left(\frac{1}{\pi n}\cdot sh\frac{\pi na}{2b} + \frac{a}{4b}(1-\mu)\cdot ch\frac{\pi na}{2b}\right) = 0$$

(32)

Due to (31) condition, results the equation:

$$-\frac{3072Cb^5(-1)^{\frac{n+3}{2}}}{(\pi n)^6}\frac{2-\mu}{1-\mu} + A_n\cdot sh\frac{\pi na}{2b} - B_n\cdot ch\frac{\pi na}{2b} - 2C_n b\left(\frac{1+\mu}{1-\mu}\frac{1}{\pi n}\cdot sh\frac{\pi na}{2b} - \frac{a}{2b}\cdot ch\frac{\pi na}{2b}\right) + 2D_n b\left(\frac{1+\mu}{1-\mu}\frac{1}{\pi n}\cdot ch\frac{\pi na}{2b} - \frac{a}{2b}\cdot sh\frac{\pi na}{2b}\right) = 0 \qquad (33)$$

From the equations (28) ÷ (33) there are obtained A_n, B_n, C_n and D_n. Introducing A_n, B_n, C_n and D_n values in relation (26), the elastic deformation w can be obtained for any p_0 value. [4, 5, 6]

The mechanical characteristics of the recoverable belt conveyors materials and this analytical method compared with FEM simulation are used to determine the elastic deformations and moments for modular panels made on recyclable belt conveyors. [1, 4, 5, 6]

Due to this method were designed the modular metallic supports (figure 1) able to be mounted for operative assembling in raising dyke and evacuation drains to reduce the floods effects.

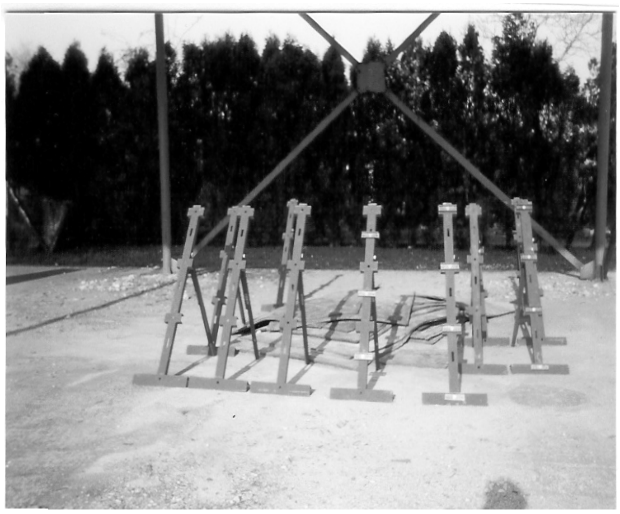

Figure 1

4. Conclusion

The paper presents a theoretical and experimental interdisciplinary research finished by making drain channels and aggradations dyke directly along of the river bed, made of rubber modular elements which could be mounted with maximum promptitude, the configuration of the ground having small importance and with no intervention of heavy equipment.

The new method recommends the recycling of rubber belt conveyors which are impossible to be recoverable for mining industry.

The recycling of these materials is possible due to a modular designing of the rubber recovered panels, which could be efficient assembled as drain channels and levee dyke directly along the river bed, in zones where floods' effects could be reduced.

The study of mechanical characteristics of the recoverable rubber belts allow the analysis of implementation possibilities of new recyclables used materials method, for making modular panels whose conception allows the operative assembling for raising dyke height and evacuation drains for eliminate / prevent / reduce the floods effects.

The specific weight of the chosen size belts, recommends *2-2,5m* length panels, size adopted from point of view of storing during the transport and in some time for easier of manipulation and assembly possibilities.

This method permits to estimate the modular panels mounted in $30^\circ \div 75^\circ$ angle positions, which are stressed by the static water pressure with *1,2m* depth or stressed by dynamic water pressure caused by up to *5m/s* water velocity.

These experimental data aid to choice the panel assembling type, respectively for assembly panels on metallic supports special designed for positioning the modular elements on land's configuration.

Ecological priorities

The global evaluation of the implementation impact of this new method to prevent natural and accidental floods is focused on the elimination of specific actions determined by floods: the flooding of surfaces determine the biotope of those zones modification; soil erosion and sedimentations that can lead to major modification of the soil (ground sliding; losing of versants stability); accumulation of degradable materials in contact with the ground, the flooding of sewerage system and water purifying stations; several changes of water quality; the interruption of economical and social activities etc.

Social-economics priorities

The environment's protection programmes adopted in the EU should increase the aim of education and research activity. New jobs could be created, especially in unpropitious areas from the mining field activities where could be organized SME relied on this kind of recycling method.

This paper represents a contribution in the eco-designing and can recommend new research directions:

- the influence of environment's factors must be taken in consideration, from the beginning of product or technology design;
- setting up the role and responsibilities for each partner in the making chain of a product: producers, distributors, consumers;
- the development of policies for promoting innovations in all activities frames with a special impact on environment;
- renewal of the designing of products, taking into account the recycling and recovery technologies;
- the consumers training in order to accept the new products made by technologies with no impact on environment;
- development of knowledge in this specific field by the promotion of high level interdisciplinary courses in the Universities system.

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