Considerations on Recyclable Materials Mechanical Engineering for Sustainable Development Concept in Oltenia Region

ADRIAN ROSCA [1)], DANIELA ROSCA [2)]
1) Horticulture Faculty, 2) Electromecanics Faculty
University of Craiova
13 A. I. Cuza Street, 200585, Craiova
ROMANIA
adrosca2003@yahoo.com, http://www.ucv.ro

Abstract: The paper present general issues and current state concerning the environment in Romania and the Sectorial Operational Programme for Environment. There are presented collaborative and interdisciplinary universitary mechanical engineering research activities to assist government agencies, local and regional communities and industrial companies for better implementation of recyclable materials concept to meet the continuous changing needs of the environmental engineering goals for regional sustainable development.

Key-Words: - Mechanical and environmental engineering, Recyclable materials, Sustainable development

1. General Issues for Romanian Policy Concerning Environmental Sectorial Operational Programme

Romania is the thirteenth country in Europe as size (238,391 km^2 area) and according to statistical data for 2006, has a population of about 20.6 million inhabitants.

Natural resources represent an essential part of Romania's richness and the exploitation of these resources, both renewable and non-renewable raw material, determines the social and economic development of the country, environmental status and living conditions of the population. In order to contribute to the quality of life in Romania, natural resources need to be exploited in a sustainable development manner. This mission is to find ways to increase the total wealth at the same time with prudently use of natural resources, so as the renewable sources to be maintained and nonrenewable sources to be used taking into account the needs of future generation. [10,11,12]

Current state of the environment

Water resources. Romania is endowed with all types of fresh water resources (rivers, natural and artificial lakes, the Danube River and the ground waters). The largest resource of fresh water comes from the Danube and other rivers. The usable water resource is 2,660 m^3/inhabitant/year, compared with the European average of 4,000 m^3/inhabitant/year.

This difference is largely due to the reserves contamination in the past, linked to domestic and economical activities with no consideration of environmental protection. [10,11,12]

Wastewaters. The volume of wastewaters discharged in 2006 was 3,334 million m^3, of which almost 60% that have to be treated. In the total volume of waste- water needed to be treated, approximately 30% have been sufficiently treated, while other almost 70% of wastewater was discharged into the natural receivers, especially rivers, untreated or insufficiently treated. This is mainly due to the lack or insufficient treatment facilities across the country.[10,11,12]

Water pollution is one of Romania's largest environmental issues. Water pollution from household, industrial and agricultural sources has a negative impact on fish breeding, irrigation, and drinking water supplies. Poor water quality arises mainly from poor controls over industrial effluents and discharges and from inadequate wastewater infrastructure. [10,11,12]

Flood risk. There have been some catastrophic floods in recent years resulting in loss of human and animal lives and drastic alterations to the landscape. Their frequency, and their proportion, is increasing. It is supposed that this flooding is due to climate change, modification of riverbeds and unauthorized land clearings. The most vulnerable areas are the Crisuri, Somes, Mures, Tarnave, Timis, Olt, and Arges river basins.

Soil quality. Preliminary studies on soils pollution in Romania indicate around 900,000 ha affected by different types of pollutants on certain levels of pollution. The most notable factors that lead to the pollution/degradation of soils are: mining and quarry activities; ponds, mining dumps, non-complying landfills; inorganic residues and waste (minerals, inorganic material, metals, salts, acids, alkalis); salted waters from petroleum extraction, petroleum pollution; air-transported substances (hydrocarbons, ammonia, sulphur dioxide, chlorides, fluorides, nitrogen oxides, lead compounds). Although recently some industrial plants have been closed and others have reduced their activity soil pollution maintains high in the affected areas.

Waste management represents one of the most serious environmental protection problems in Romania. Romanian statistics distinguish between two categories of waste: municipal waste and waste similar to it, and production waste. Land filling is the main method for municipal waste disposal. The municipal landfill inventory records 251 registered sites, out of which only 18 landfills will be in EU regulations conformity by the end of 2006. The remaining landfills that do not conform to EU regulations are scheduled to cease to operate, gradually by 2017. There are no organized waste management services in most of the rural areas; this leading to a high number of unauthorized landfills highly affecting the environment and the population.

The waste production remains very high while the separate collection of waste and waste recycling are still slowly improving. The waste related legislation in Romania, now in line with EU acquits, imposed positive changes over the past years, but many efforts are still needed to meet compliance with the European standards. [1,10,11,12]

Emissions of atmospheric pollutants, originating from fossil-fuelled large combustion plants (LCP) that generate heat and electricity have a significant environmental impact. There are 175 LCP but only 9 comply with Directive EC/80/2001; these plants emit high concentrations of particulates, and nitrogen and sulphur oxides, which cause acid rain and cause a significant health risk, mainly in urban industrial areas. The main origin of Romania's poor urban air quality is low-grade fuel. The thermal energy sector is still relying on low efficiency of solid fuels, on sulphur high-content in heavy fuel and low-income families in towns rely on poor-quality coal for heat. Transport is also a increasing factor in low urban air quality as a large proportion of cars are old and poorly maintained, running on petrol that has the one of the highest lead content among Eastern European countries. This later factor is however decreasing due to changes in the legislation aiming to meet European standards.[1,3,10]

In Romania, the for Environment (SOP ENV) is closely linked to the national objectives of the strategy laid down in the National Development Plan (NDP) and National Strategic Reference Framework (NSRF), which takes into consideration the European Union's supporting principles and practices. It is designed to lay the foundation and be a catalyst for a more competitive economy, a better environment and more balanced regional development. [10,11,12]

The overall objective of SOP is to protect and improve the environment and living standards in Romania. The aim is to reduce the environment infrastructure gap, both in terms of quantity and quality, which exists between the European Union and Romania. The programme covers the period of 2007-2013, but its objectives also look forward to Romania's development needs beyond 2013 by laying the foundations for sustainable economic development. It will contribute to Romania meeting its EU obligations to the environment sector, particularly in the less developed regions of the country. SOP also describes the priority axes, intervention areas key and projects identification, as well as the implementation provisions.

2. Environment Protection in Oltenia Region

Oltenia Region in situated in south-west of Romania has 29212 km^2, which represents 12.3% of Romania area and its 2 million inhabitants' represents 10.3% of Romania population. *Oltenia Region* (Fig. 1) is composed in five counties [10,11]:

Dolj-7,414 km^2/744,000 inhabitants;
Gorj-5,602km^2/395,000 inhabitants,
Mehedinti-4,933km^2/322,000 inhabitants,
Olt-5,498km^2/508,000 inhabitants,
Vâlcea-5,765km^2/431,000 inhabitants.

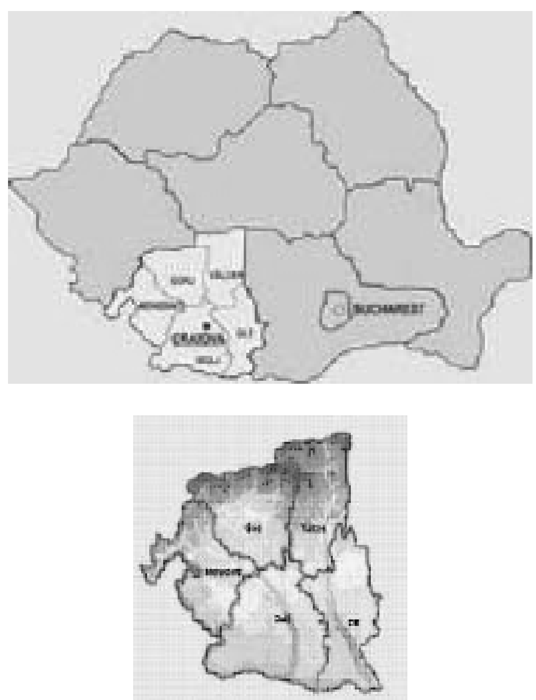


Fig. 1

In 2000, in *Oltenia Region* were registered approx. 26,800 enterprises (the figure representing only the enterprises organized as commercial enterprises, not budgetary): 66 mining activity; 2967 manufacturing activity; 59 electrical and thermal energy, gasses and water activities; 19775 en gross and en detail commerce, maintenance activities; 940 hotels and restaurants activities; 681 transport and deposits activities; 57 post and telecommunications activities; 841 services activities; 41 education activity; 217 heath and social assistance.

The large enterprises (780) activity concern in manufacturing, construction, transports, mining, energy, gasses and water, and the SME activities is represented by commerce, services and distribution.

An important environment impact is produced by large enterprises activities: the largest Romanian electrotechnical industry company in *Dolj* county, automobile industry in *Dolj* county, cement plant in *Gorj* county, 7 large combustion plants in *Dolj, Gorj, Mehedinti* and *Valcea* counties, one of the most important sun flower oil company in *Dolj* county, 2 important chemical companies in *Dolj* and *Valcea* counties, the largest Romanian aluminum making company in *Olt* county, the most important European havy-water producer in *Mehedinti* county.

In *Dolj*, *Olt* and *Valcea* counties the agricultural and horticultural domains represent one of the important activities.The main problems affecting the environment in *Oltenia Region*'s counties is caused by soil erosion and the danger of desertification within *Dolj* and *Olt* counties, the *soil quality is damaged due to mining activities in Gorj and Mehedinti counties* and chemical substances affect *Dolj* and *Valcea* counties. [10,11,12]

The elaborated legislation insists on more rational resource using, for a higher efficiency. The recycling of products, become an important objective of the sustainable resources conservation. [9]

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 University of Craiova, with more then 24,000 students in 17 faculties is representative in academic education in *Oltenia Region*. In the University of Craiova the environmental engineering education is realised in the Faculty of Electomechanics for *Environmental Engineering in Industry*, and in The Faculty of Horticulture for *Environmental Engineering in Agriculture*. The University has to enhance the understanding and adoption of sustainable development principles through education, outreach, research and community involvement, to promote, to facilitate and to offer interdisciplinary education; and, through community-based program development and applied research, to work with local and regional communities and government agencies to further sustainable development at a variety of scales.

A primary goal is to create collaborative and interdisciplinary approach to assist government agencies, local and regional communities and industrial companies for better meet of the changing needs into: new technologies and industries; intensified reuse of materials and equipment; migration to renewable energy sources; more efficient use of natural resources; global climate change and its effects on population and industry and agriculture; creating profitable new ventures which are environmentally sustainable; targeting and penetrate newly emerging green industry markets; incorporating environmental concerns into strategic planning at all levels.

In the last years, the research activities are interested in finding new methods to reduce the floods effects. [1, 3, 6]

The assessment schema of the impact produced by hydro technical activities 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.

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. [6]

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 plan in which these stocks and their location in zones where the floods danger could appear, is made by IJPCUS (Departmental Civil Protection Inspection and Urgent Situations) and CNAR. (Romanian Water National Company).

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

In order to improve the water- tightness for all the dyke height, a recent method recommends consolidating the dyke with sand sacks covered with polyethylene thin sheets.

Fig. 2

Fig. 3

During the floods in south of Oltenia Department few years ago, it was observed that due to the dynamic motion of the water, this method was not enough to prevent the broken of the dykes (Fig. 2).

In the Romanian National Lignite Company in *Gorj County* is using more then 300 km belt conveyors with textile insertions PES/PA type (polyester/polyamide), CV/PA type (viscose/ polyamide) and with steel cord (ST type) conveyor belts.

Fig. 4

These belt conveyors represent the coal transport system of the surface coal mine milling complex equipment (Fig. 3, Fig. 4).

In last years after closing several surface coal mines, there are more than 200km advanced used belt conveyors which can not be repaired for mining utilization.

It must be specified that during working-time, the belts with no more than 25-30% ware degree, might be repaired in special workshops, but the durability of these belts is *20-30%* smaller than the new belts. [2, 5]

These belt conveyors categories are characterized by the main parameters: belt tensile strength *250 – 4000 N/mm*; belt thickness 8 - *25 mm*; approximate mass 10– *30* kg/m^2.

The new proposed method concerns in recovery and recycling the belt conveyors with an expired duty life.

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

To determine the recovering and recycling possibilities for end-life belt conveyors materials, samples of steel cable insertion (ST) conveyor belts, with up to *80%* wear rate, were tested in order to establish the longitudinal tensile strength of the belts and the specific pulled out strength steel cable according to STAS 10674-2002. [5,6,7]

To determine the recovering and recycling possibilities for end-life belt conveyors materials, samples of belt conveyors with up to *80%* wear rate, 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 8915-2002).

3. Considerations on Recyclable Materials Mechanical Engineering

During the floods, the dykes are static distribution loaded by the water' pressure or dynamic stressed by the water velocity and by the water swirl movement. In the static and in the dynamic loading, the slope wall and the base of the ground dykes are eroded due to the abrasive action of mineral particles floating in the water.

In order to prevent or to reduce the effect of an incipient crack in the ground dyke is necessary to cover the incipient crack with an impermeable material. The choosing of this impermeable material has to consider the mechanical characteristics and the elasticity properties of the covering surface.

To cover the incipient crack is possible to use rigid metallic thin plates (too heavy to be operative mounted) or flexible recyclable belt conveyor plates.

The elastic deformation of the squared plate can be calculated for four technical situations. According to previous theoretical and practical considerations, the water pressure $p_0=1bar$ determines no dangerous deformation of the flexible recyclable belt conveyor plates. Therefore the following data take in consideration the dynamic loads produced by the water velocity (the dynamic coefficient is multiplying the static pressure effect with 3, 6, 12).

The elastic deformation calculus take in consideration the admissible tensile of the flexible plate material ($2a = 2{,}5m;\ 2b = 1{,}2m$), which was experimentally determined for different ware grade of the used recyclable belt conveyor. [2,7,8]

3.1. Three sides embedded squared plate

To determine the maximum deformation of the static loaded plate, it was considered that the metallic plate $2a \times 2b$ is three sides embedded and is loaded by water pressure with a linear variation on x axe, as is presented in Fig. 5. [4,7,8]

The linear variation of the pressure is proposed to be given by the relation:

$$p = \frac{p_0}{2a}\left(a+x\right), \tag{1}$$

where the p_0 is the maximum pressure.

The deformation on the center of the plate is given by the relation:

$$\begin{aligned} w = {} & C\left(a+x\right)\left(y^4 - 6b^2y^2 + 5b^4\right) + \\ & \sum_{1,3,5,\ldots}^{\infty}\left[A_n \cdot ch\frac{\pi\, n}{2b}x + B_n \cdot sh\frac{\pi\, n}{2b}x\right]cos\frac{\pi\, n}{2b}x + \\ & \sum_{1,3,5,\ldots}^{\infty}\left[C_n \cdot x \cdot sh\frac{\pi\, n}{2b}x + D_n \cdot x \cdot ch\frac{\pi\, n}{2b}x\right]cos\frac{\pi\, n}{2b}x \end{aligned} \tag{2}$$

where $C = \frac{p_0\left(1-\mu^2\right)}{4aEh^3}$ (E- elasticity modulus; μ- Poisson coefficient; h- thickness of the wall).

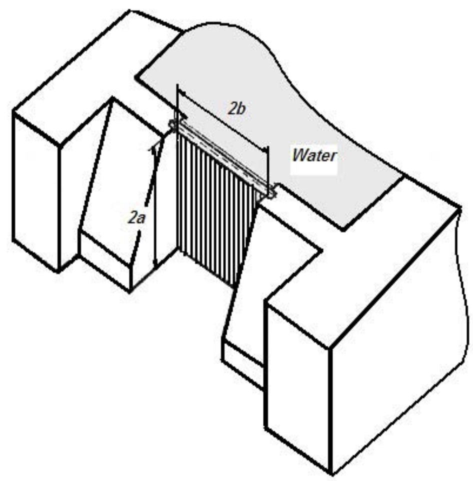
For any values of the arbitrary constants A_n, B_n, C_n and D_n, the function w must satisfy the boundary conditions for y and x.

For $y = \pm b$

$$\left|w\right|_{y=\pm b} = 0 \quad , \quad \left|\frac{\partial^2 y}{\partial y^2}\right|_{y=\pm b} = 0 \tag{3}$$

and in the same time the deformation w must respect the condition

$$\frac{p}{D} = \frac{\partial^4 w}{\partial x^4} + 2\frac{\partial^4 w}{\partial x^2 \cdot \partial y^2} + \frac{\partial^4 w}{\partial y^4} \tag{4}$$



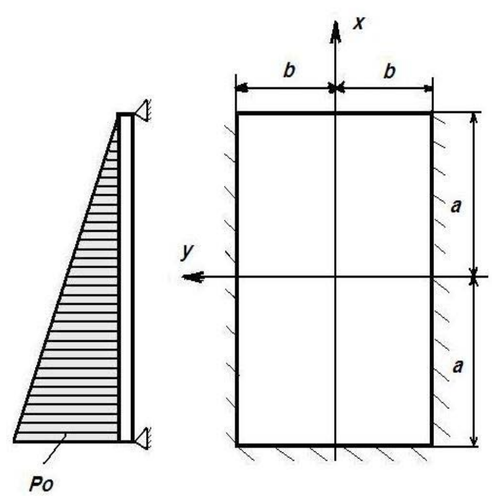


Fig. 5

For $x = \pm a$ it is necessary to take into account that the boundary limited by $x = +a$ can be considered as *simple support*, and the boundary limited by $x = -a$ can be considered as *free boundary*.

For $x = +a$, the limits are given by the relations

$$\left|w\right|_{x=a} = 0 \quad ; \quad \left|\frac{\partial^2 w}{\partial x^2}\right|_{x=a} = 0 \tag{5}$$

Considering the technical limits of the real plate, the first condition (5) determines the relation

$$\frac{3072 \cdot C \cdot a \cdot b^4 \left(-1\right)^{\frac{n+3}{2}}}{\left(\pi n\right)^5} + A_n \cdot ch\frac{\pi na}{2b} + B_n \cdot sh\frac{\pi na}{2b} + C_n \cdot a \cdot sh\frac{\pi na}{2b} + D_n \cdot a \cdot ch\frac{\pi na}{2b} = 0 \tag{6}$$

and the second condition (5) determines the relation

$$A_n \cdot ch\frac{\pi na}{2b} - B_n \cdot sh\frac{\pi na}{2b} + 4\,C_n b\left[\frac{1}{\pi n} \cdot ch\frac{\pi na}{2b} + \frac{a}{4b} \cdot sh\frac{\pi na}{2b}\right] + 4\,D_n b\left[\frac{1}{\pi n} \cdot sh\frac{\pi na}{2b} + \frac{a}{4b} \cdot ch\frac{\pi na}{2b}\right] = 0 \tag{7}$$

After eliminating A_n and B_n in the last two equation, results

$$w = \frac{p\left(1-\mu^2\right)}{2Eh^3}[[x^4 - 6a^2x^2 + 5a^4 + \frac{1536a^4}{\pi^4}\sum_{1,3,5...}^{\infty}\left(n^4 \cdot ch\frac{\pi nb}{2a}\right)^{-1} \times [-\left(\frac{1}{\pi n} + \frac{b}{4a} \cdot th\frac{\pi nb}{2a}\right) \cdot ch\frac{\pi ny}{2a} + \frac{y}{4a} \cdot sh\frac{\pi ny}{2a}] \cdot sin\frac{\pi n(a+x)}{2a}] \tag{8}$$

For $x = -a$, the limits must consider that the bending moment M_y and the reaction force are zero:

$$M_y = 0 \quad or \quad \frac{\partial^2 w}{\partial x^2} + \mu\frac{\partial^2 w}{\partial y^2} = 0$$
$$T_y - \frac{\partial M_{xy}}{\partial x} = 0 \quad or \quad \frac{\partial^3 w}{\partial x^3} + \left(2 - \mu\right) \cdot \frac{\partial^3 w}{\partial x \cdot \partial y^2} = 0 \tag{9}$$

Considering the technical limits of the real plate, the first condition (9) determine the relation

$$A_n\left(1-\mu\right) \cdot ch\frac{\pi na}{2b} - B_n\left(1-\mu\right) \cdot sh\frac{\pi na}{2b} + 4\,C_n b\left[\frac{1}{\pi n} \cdot ch\frac{\pi na}{2b} + \frac{a}{4b}\left(1-\mu\right) \cdot sh\frac{\pi na}{2b}\right] - 4\,D_n b\left[\frac{1}{\pi n} \cdot sh\frac{\pi na}{2b} + \left(1-\mu\right)\frac{a}{4b} \cdot ch\frac{\pi na}{2b}\right] = 0 \tag{10}$$

and the second condition (9) determine the relation

$$-\frac{3072 \cdot C \cdot a \cdot b^5 \left(-1\right)^{\frac{n+3}{2}}}{\left(\pi n\right)^6} \cdot \frac{2-\mu}{1-\mu} + A_n \cdot sh\frac{\pi na}{2b} - B_n \cdot ch\frac{\pi na}{2b} - C_n \cdot b\left(\frac{1+\mu}{1-\mu} \cdot \frac{1}{\pi n} \cdot sh\frac{\pi na}{2b} - \frac{a}{2b} \cdot ch\frac{\pi na}{2b}\right) + 2\,D_n \cdot b\left(\frac{1+\mu}{1-\mu} \cdot \frac{1}{\pi n} \cdot ch\frac{\pi na}{2b} - \frac{a}{2b} \cdot sh\frac{\pi na}{2b}\right) = 0 \tag{11}$$

Using the relations 7, 8, 10 and 11 the values for coefficients C_n, D_n, A_n and B_n, can be obtained with the following relations

$$C_n = \frac{768\,C\,b^4\left(-1\right)^{\frac{n+3}{2}}}{\left(\pi n\right)^4} + [-2\left(2-\mu\right)\frac{1}{\left(\pi n\right)^2} \cdot sh\frac{\pi na}{2b} - \frac{\mu}{\pi n}\frac{a}{b} \cdot \left(ch\frac{\pi na}{2b}\right)^{-1} + \frac{a}{b}\left(3+\mu\right)\frac{1}{\pi n} \cdot ch\frac{\pi na}{2b} + \frac{a^2}{2b^2}\left(1-\mu\right) \cdot sh\frac{\pi na}{2b}] \times \left[\left(3+\mu\right)\frac{1}{\pi n} \cdot ch\frac{\pi na}{b} + \frac{a}{b}\left(1-\mu\right) \cdot \left(sh\frac{\pi na}{b}\right)^{-1}\right]^{-1}$$

$$D_n = \frac{768\,C\,b^4\left(-1\right)^{\frac{n+3}{2}}}{\left(\pi n\right)^4 \cdot \left(sh\frac{\pi na}{2b}\right)} - C_n \cdot cth\frac{\pi na}{2b}$$

$$B_n = \frac{1536 \cdot \mu\,C\,ab^4\left(-1\right)^{\frac{n+3}{2}}}{\left(1-\mu\right)\left(\pi n\right)^5 \cdot sh\frac{\pi na}{2b}} - 4\,D_n b\left[\frac{1}{\left(1-\mu\right)\pi n} + \frac{a}{4b} \cdot cth\frac{\pi na}{2b}\right]$$

$$A_n = \frac{1536 \cdot \mu\,C\,ab^4\left(-1\right)^{\frac{n+3}{2}}}{\left(1-\mu\right)\left(\pi n\right)^5 \cdot ch\frac{\pi na}{2b}} - 4\,C_n b\left[\frac{1}{\left(1-\mu\right)\pi n} + \frac{a}{4b} \cdot th\frac{\pi na}{2b}\right] \tag{12}$$

Using relations (11), because for a real plate with $a = 1,5b$, the coefficient values are given by relations

$$C_1 = 0,904\,C\,b^4\,;\ D_1 = 1,34\,C\,b^4\,;$$
$$A_1 = -\,2,375\,C\,b^5\,;\ B_i = -\,3,865\,C\,b^5$$
$$C_3 = -\,0,000115\,C\,b^4\,;\ D_3 = -\,0,000134\,C\,b^4\,;$$
$$A_3 = 0,00022\,C\,b^5\,;\ B_3 = 0,00026\,C\,b^5. \tag{13}$$

Using the relation (12), in which are not considered the fifth ordain terms, the deformation w was calculated, and then the bending moments M_x and M_y were determined.

The results of these calculi are presented in Fig. 6.

Fig. 6 shows that the maximum deformation is obtained by using the relation

$$w_{max} = 0{,}78\,\frac{p_0\,b^4}{E\,h^3} \tag{14}$$

The maximum tensile in the material supporting the water pressure is given by the relation

$$\sigma_{max} = \frac{6}{h^2} M_y^{max} = \frac{6}{h^2} \cdot 0{,}19\ p_o\,b^2 \tag{15}$$

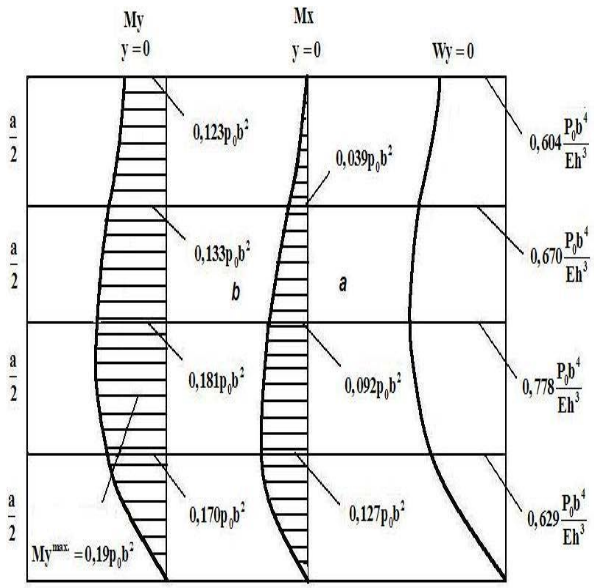


Fig. 6

The minimal normal tensile in the same point is zero, and the equivalent tensile must be smaller then the admissible tensile of the material

$$\sigma_{max} \le \sigma_{adm} \tag{16}$$

Taking into account this consideration, for a static pressure $p_0 = 3;\ 6;\ 12 bar$, the thickness of the metallic plate and the maximum deformation in the center of the plate, are presented in Table 1.

Tabel 1

h [mm]	p_0 [bar]	w_{max} [mm]
4	3	2,6
	6	5,7
	12	9,1
5	3	2,1
	6	4,8
	12	8,5
6	3	1,7
	6	4,4
	12	7,8

Using the same mathematical method for flexible recyclable belt conveyor plate, for several real thicknesses, the maximum deformations in the center of the flexible plate are presented in Table 2.

Table 2

h [mm]	p_0 [bar]	w_{max} [mm]
8	3	9,3
	6	18,5
	12	24,7
12	3	6,4
	6	11,8
	12	18,6
16	3	4,6
	6	7,4
	12	10,2

3.2. Simple laid on entire perimeter squared plate

A squared plate $2a\times 2b$ static loaded by an uniform distributed pressure can be symmetrically deformed in rapport with x and y axis; therefore the deformation function w has to be a pare one in rapport with x and y axis.

For the given laid conditions the deformation function w can be zero on the perimeter of the squared plate, and in the same time for $x = \pm a$ must results $M_x = 0$, and for $y = \pm b$ must results $M_y = 0$.

Taking into account these conditions, the deformation w can be determined with the relation

$$w = \frac{p\left(1-\mu^2\right)}{2Eh^3}[[x^4 - 6a^2x^2 + 5a^4 + \frac{1536a^4}{\pi^4}\sum_{1,3,5\ldots}^{\infty}\left(n^4 \cdot ch\frac{\pi nb}{2a}\right)^{-1} \times$$
$$\times[-\left(\frac{1}{\pi n} + \frac{b}{4a}\cdot th\frac{\pi nb}{2a}\right)\cdot ch\frac{\pi ny}{2a} + \frac{y}{4a}\cdot sh\frac{\pi ny}{2a}]\cdot sin\frac{\pi n(a+x)}{2a}] \tag{17}$$

The maximum deformation can be obtained in the center of the squared plate (for $x = y = 0$), using the relation

$$w_0 = \frac{p\,a^4\left(1-\mu^2\right)}{2\,Eh^3}\cdot\left[5 - \frac{1536}{\pi^4}\right)\sum_{1,3,5\ldots}^{\infty}\left(sin\,\frac{\pi n}{2}\right)\times$$
$$\times\left(\left(n^4\cdot ch\,\frac{\pi nb}{2a}\right)^{-1}\cdot\left(\frac{1}{\pi n} + \frac{4}{4a}\cdot th\,\frac{\pi nb}{2a}\right)\right] \tag{18}$$

For $a = 2b$, the maximum deformation is obtained with relation

$$w_0 = 2{,}127\cdot\frac{pa^4}{h^3}\cdot\frac{1-\mu^2}{E} \tag{19}$$

Using this mathematical method given by relations (18) and (19) for flexible recyclable belt conveyor plate, for belt thicknesses caused by high ware grade, the maximum deformations in the center of the flexible recyclable belt conveyor plate are presented in Table 3.

Table 3

h [mm]	p_0 [bar]	w_{max} [mm]
8	3	10,5
	6	19,4
	12	25,3
12	3	7,8
	6	13,7
	12	19,3
16	3	5,8
	6	9,6
	12	13,7

3.3. Embedded squared plate on entire perimeter

The deformation in the center of $2a \times 2b$ squared plate embedded on the entire perimeter, which is uniform distributed stressed by water pressure *p*, must take in consideration the equation of the elastic surface

$$w = \frac{w_0}{4} \cdot \left(1 + \cos\frac{\pi x}{a}\right)\left(1 + \cos\frac{\pi y}{b}\right) \quad (20)$$

Because this equation must respect the embedded conditions

- for $x = \pm a$: $w = 0$; $\frac{\partial w}{\partial x} = 0$; (21)

- for $y = \pm b$ **:** $w = 0$; $\frac{\partial w}{\partial y} = 0$,

the maximum deformation is obtained with relation

$$w_0 = 192\, \frac{pa^4}{Eh^3} \cdot \frac{1-\mu^2}{\pi^4} \cdot \left(3 + 3\frac{a^4}{b^4} + 2\frac{a^2}{b^2}\right)^{-1} \quad (22)$$

Using the mathematical method given by relations (20) and (22) for flexible recyclable belt conveyor plate, for belt thicknesses caused by high ware grade, the maximum deformations of the flexible recyclable belt conveyor plate are presented in Table 4.

Table 4

h [mm]	p_0 [bar]	w_{max} [mm]
8	3	6,5
	6	16,4
	12	21,3
12	3	4,8
	6	8,7
	12	15,3
16	3	3,8
	6	5,6
	12	8,7

In Table 4 is observed that maximum deformations of the squared plate with entire perimeter embedded are smallest in compare with the previous situations.

3.4. Simple laid on two opposite sides and embedded on two opposite sites squared plate

The equation of the elastic surface of $2a \times 2b$ plate, simple laid on two sides $y = \pm b$ and embedded on two opposite sites $x = \pm a$, which is stressed by uniform distributed water pressure *p*, is given by the relation

$$w = \frac{w_0}{2} \cdot \left(1 + \cos\frac{\pi x}{a}\right) \cdot \cos\frac{\pi y}{2b} \quad (23)$$

Taking in consideration the contour limits, the maximum deformation is obtained with relation:

$$w_0 = 192\, \frac{pa^4}{Eh^3} \cdot \frac{1-\mu^2}{\pi^5} \cdot \left(\frac{3}{16} + \frac{a^4}{b^4} + \frac{b^2}{2a^2}\right)^{-1} \quad (24)$$

Using the mathematical method given by relations (23) and (24) for flexible recyclable belt conveyor plate, for belt thicknesses caused by high ware grade, the maximum deformations of the flexible recyclable belt conveyor plate are presented in Table 5.

Table 5

h [mm]	p_0 [bar]	w_{max} [mm]
8	3	11,9
	6	21,8
	12	27,4
12	3	9,6
	6	16,1
	12	22,5
16	3	7,5
	6	11,3
	12	17,7

The values in Table 5 are the larger obtained in these four situations, but due to the elasticity of the belt conveyor material could resist at higher dynamic loads produced by water velocity and heavy floating impact objects.

4. Conclusion

The research activity of the Faculty of Electomechanics for *Environmental Engineering in Industry* specialization, and in the Faculty of Horticulture for *Environmental Engineering in Agriculture* specialization include, among other subjects, the environment and the proper use of resources; basic scientific research and the application of the results of science and technology in the interests of sustainable development.

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

The study of mechanical characteristics of the recoverable conveyors belts permits to analyze the implementation possibilities of recyclables high ware grade materials for making modular elements to prevent or to reduce the floods effects.

The paper presents mathematical and experimental interdisciplinary research to determine the maximum elastic deformation of recyclable belt conveyors plates, to be used as modular consolidation elements for dykes to prevent and to decrease the flood effects.

The maximum deformation values in the center of elastic plate made in recyclable belt conveyors and the smaller weight of these modular elements recommend using the recyclable belt conveyors elements for operative activities to prevent the floods effects.

Due to this mathematical method were designed and made modular elastic elements able to be mounted with operative assembling (Fig. 7).

These modular consolidation elements for dykes can be mounted with maximum promptitude, with no heavy equipment intervention.

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 manipulation. *This new method was tested with very good results to prevent the dyke broken /cracking due to the swirl motion of the water during the floods happened few years ago is south of Oltenia* (Fig. 8).

Social and economical priorities

In the economic and social context of Romania, the area approached by this project is found in the priorities of scientific research and innovation plan concerning new measures and methods in the environment's protection, in new technologies for recovery and recycling the used life end materials.

New jobs were created, especially in unpropitious areas from the surface mining activities where could be organized SME relied on this kind of recycling method.

This paper represents a contribution in the eco-designing and recommends new research directions: 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 environment impact; development of knowledge in this specific field by the promotion of high level interdisciplinary courses in the University system.

Fig. 7

Fig. 8

Ecological priorities

The global evaluation of the implementation impact of this new method to prevent natural and accidental floods is focused to eliminate the 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.

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