“OVIDIUS” UNIVERSITY OF CONSTANTZA
UNIVERSITATEA „OVIDIUS” CONSTANȚA

“OVIDIUS” UNIVERSITY ANNALS - CONSTANTZA

Year VIII
(2006)

Series: CIVIL ENGINEERING

ANALELE
UNIVERSITĂȚII „OVIDIUS”CONSTANȚA

ANUL VIII
(2006)

Seria: CONSTRUCȚII

Ovidius University Press
2006

SECTION I
Calculus and Structures Reliability
Architecture

SECTION II
Hydraulic Structures
Materials and New Technologies

ISSN-12223-7221

Shear Connection Design of Concrete-Encased Steel Section Columns

Ştefan I. GUŢIU [a] Cãtãlin MOGA [a] Ioan PETRAN [a] Gabriel URIAN [a]
[a] *Technical University Cluj Napoca, Cluj Napoca, 400020, Romania*

Rezumat: În lucrare se prezintã calculul conexiunii la interfaţa dintre componenta oţel şi componenta beton produsã de acţiunea forţei tãietoare, în cazul stâlpilor cu secţiune compusã oţel-beton, realizaţi în soluţia constructivã de profile metalice înglobate în beton. Lucrarea include de asemenea un exemplu numeric privind evaluarea eforturilor longitudinale de lunecare şi calculul conectorilor mecanici.

Abstract: This paper presents the design of the shear connection over the interface between the structural steel component and the encased concrete. A numerical example for the evaluation of the longitudinal shear stresses in case of a column with a concrete encased section and the design of the mechanical shear connectors are also presented here.

Keywords: *composite columns, shear connection, mechanical connectors.*

1. Introduction

In case of the composite steel-concrete columns, the mechanism by which shear stresses can be transferred over the interface between the structural steel component and the encased concrete are adhesion, interface interlocking and friction, which are referred to as the *natural bond.* If the natural bond is not enough to achieve the required shear resistance mechanical shear connectors may be used, the widely used types being headed studs and the shot-fired nails.

In this paper an analytical method for the evaluation of the longitudinal shear stresses and the design of mechanical shear connectors are presented.

A numerical example, which is also given here, can be useful for the design of composite steel-concrete columns.

2. Mechanical shear connectors

There exist a large variety of mechanical shear connectors, which can be used to improve the shear resistance in a steel-concrete interface, but not all are suited for the use of columns.

The most widely type of mechanical shear connectors is the headed stud, which consists of a bolt that is electrically welded to the steel member. The shear forces are transferred by dowel action, which will cause high concentrated stresses in the surrounded concrete, Figure 1.a. Another shear connector is the shot-fired nail. The nails are thinner than the studs, and consequently easier to deform, which makes the dowel action less pronounced, Figure 1.b.

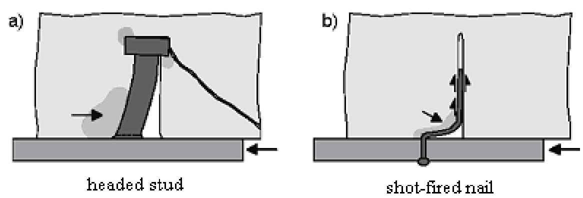


Fig. 1

Where stud connectors are attached to the web of a fully or partially concrete encased steel I-section or a similar section, account may be taken of the frictional forces that develop from the prevention of lateral expansion of the concrete by the adjacent steel flange.

ISSN-12223-7221

In accordance with EC 4, the additional resistance, P, may be added to the calculated resistance of the shear connectors, on each flange and each horizontal row of studs, as shown in figure 2.

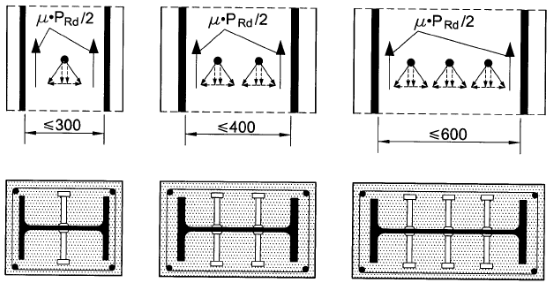


Fig.2

The value of the additional resistance P is:

$$P = \mu \cdot P_{Rd} / 2 \qquad (1)$$

where:

- μ - the relevant coefficient of friction;
- P_{Rd} - the resistance of a single stud.

The design shear resistance of a headed stud automatically welded in accordance with EN 14555 should be determined from:

$$P_{Rd} = \min \begin{cases} \dfrac{0.8 f_u \pi d^2 / 4}{\gamma_v} \\ \dfrac{0.29 \alpha d^2 \sqrt{f_{ck} \cdot E_{cm}}}{\gamma_v} \end{cases} \qquad (2)$$

where:

$$\alpha = \begin{cases} 0.2\left(\dfrac{h_{sc}}{d} + 1\right) - \text{for: } 3 \le h_{sc}/d \le 4 \\ 1 - \quad \text{for: } \quad h_{sc}/d > 4 \end{cases}$$

γ_v - the partial safety factor, $\gamma_v = 1.25$;

d - the diameter of the shank of the stud, d = 16 mm – 25 mm;

f_u - the specified ultimate tensile strength of the material of the stud, $f_u < 500$ N/mm^2;

f_{ck} - the characteristic cylinder compressive strength of the concrete;

h_{sc} - the overall nominal height of the stud.

Shear connectors should be provided, based on the distribution of the design value of longitudinal shear, where this exceeds the design shear strength τ_{Rd}, given in Table 1.

Table 1

TYPE OF CROSS SECTION	τ_{Rd} (N/mm^2)
Completely concrete encased steel sections	0.30
Flanges of partially encased sections	0.20

3. Evaluation of longitudinal shear stresses

In order to determine the longitudinal shear at the interface between concrete and steel, the encased concrete is transformed into an equivalent steel section using the modular ratio n, Figure 3.

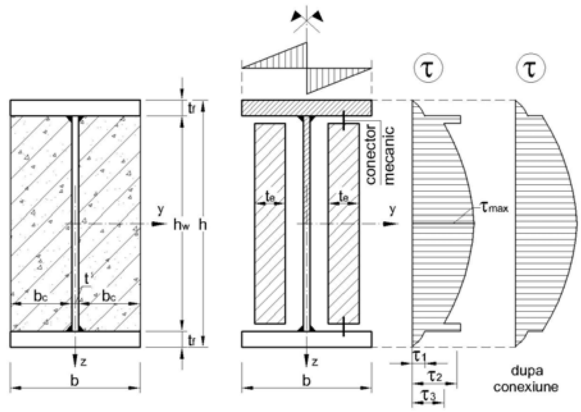


Fig.3

The equivalent in steel width of the concrete, Figure 3.b, will be:

$$t_e = \frac{b_c}{n} \qquad (3)$$

where the modular ratio can be taken as:

$$n \approx 2 \cdot n_i = 2\frac{E_a}{E_{cm}} \quad (4)$$

E_a - modulus of elasticity of structural steel;
E_{cm} – secant modulus of elasticity of concrete.

In case of the columns of type concrete encased I steel section, in the absence of a connection at the interface between steel and concrete, the shear stresses in accordance with Juravsky formula, Figure 3.c, are:

$$\tau_1 = \frac{V_{Sd}S_a}{b \cdot I} \quad (5.a)$$

$$\tau_2 = \frac{V_{Sd}S_a}{t \cdot I} \quad (5.b)$$

$$\tau_3 = \frac{V_{Sd}S_a}{(t + 2t_e) \cdot I} \quad (5.c)$$

$$\tau_{max} = \frac{V_{Sd}(S_a + \frac{1}{n}S_c)}{(t + 2t_e) \cdot I} \quad (5.d)$$

where:

- S_a – section modulus of the steel component referred to neutral axis y-y:

$$S_a = bt_f\left(\frac{h_w + t_w}{2}\right) + t\frac{h_w^2}{8} \quad (6)$$

- S_c – section modulus of the concrete referred to neutral axis y-y:

$$S_c = 2 \cdot b_c \frac{h_w^2}{8} \quad (7)$$

- I – moment of inertia of the equivalent in steel of the entire cross-section:

$$I = I_a + \frac{1}{n}I_c \quad (8)$$

The longitudinal shear force between steel and concrete will be:

$$L = (\tau_2 - \tau_3)\, t_e = \Delta\tau \cdot t_e \quad (9)$$

By replacing the shear stresses values τ_2, τ_3 into eq. (9) it results:

$$L = \frac{V_{Sd}S_a}{I}\left(\frac{1}{t} - \frac{1}{t + 2t_e}\right) \cdot 2t_e = \frac{V_{Sd}S_a}{I}\frac{4t_e^2}{t(t + 2t_e)} \quad [F/L] \quad (10)$$

The average shear stress at the interface between steel and concrete is:

$$\tau_F = \frac{L}{\sum b_i} \quad [F/L^2] \quad (11)$$

where:

$$\sum b_i = 2b_c + 2\frac{h_w}{2} = 2b_c + h_w$$

is the half perimeter of the contact surface between steel and concrete.

If: $\tau_f > \tau_{Rd}$, the natural bond is not enough to achieve the shear resistance and will be necessary to use mechanical shear connectors.

The number of the mechanical shear connectors for the entire length l of the column results from the condition:

$$N \geq L\frac{1}{P_{Rd}} = \frac{V_{Sd}S_a}{I}\frac{4t_e^2}{t(t + 2t_e)}\frac{1}{P_{Rd}} \quad (12)$$

In accordance with EC 4, the additional resistance P will be added to each connector.

4. Numerical example

The connection design for a composite steel-concrete column of type concrete encased a steel welded I-section is presented.

Design data (Figure 4)

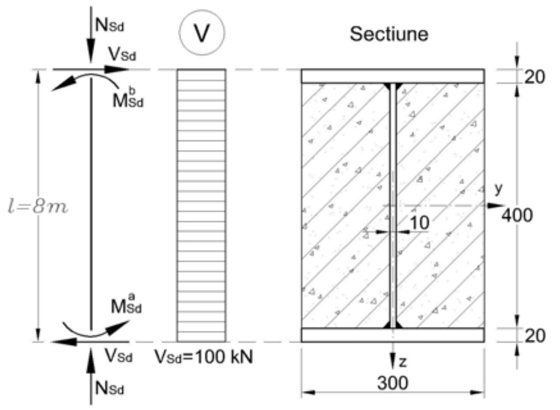


Fig.4

Materials and characteristics:

Steel grade:

S 355
- f_y=355 N/mm^2
- E_a= 210 000 N/mm^2
- I_a = 58 290 cm^4

Concrete - Class:

C 25/30:
- f_{ck} = 25 N/mm^2
- E_{cm} = 30 500 N/mm^2

$$I_c = 2\frac{14.5 \cdot 40^3}{12} = 154667 \text{ cm}^4$$

Connectors: headed welded studs:

- d = 19 mm;
- h= 85 mm;
- f_u = 450 N/mm^2
- $\gamma_v = 1.25$

Connection design

The equivalent in steel column cross-section is presented in Figure 5.

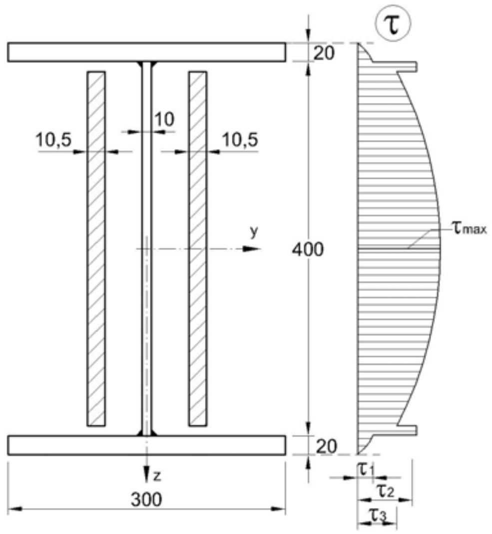


Fig.5

It results:

$$S_a = 30 \cdot 2 \cdot 21 + 20 \cdot 1 \cdot 10 = 1460 \text{ cm}^2$$

$$I = I_a + \frac{1}{n} I_c = 5890 + \frac{1}{13.8} 154667 = 69498 \text{ cm}^4$$

where:

$$n = 2 \cdot n_i = 13.8,$$

$$n_i = \frac{E_a}{E_{cm}} = \frac{210000}{30500} = 6.88$$

The longitudinal shear force is:

$$L = \frac{V_{Sd} S_a}{I} \frac{4t_e^2}{t(t+2t_e)} = 299 \text{ daN/cm}$$

where:

$$t_e = 14.5/13.8 = 1.05 \text{ cm}$$

The adhesion-friction stress over the interface between concrete and steel will be:

$$\tau_f = \frac{L}{\sum b_i} = 0.43\ \mathrm{N/mm^2} > \tau_{Rd} = 0.20\ \mathrm{N/mm^2},$$

so it results that mechanical connectors are necessary,

where:

$$\sum b_i = 2 \cdot 14.5 + 2 \cdot 20 = 69\ \mathrm{cm}.$$

The design shear resistance of a headed stud automatically welded is:

$$P_{Rd} = \min \begin{cases} \dfrac{0.8 f_u \pi d^2/4}{\gamma_v} = 81.65\ \mathrm{kN} \\ \dfrac{0.29\,\alpha\, d^2 \sqrt{f_{ck} \cdot E_{cm}}}{\gamma_v} = 73.13\ \mathrm{kN} \end{cases}$$

The number of connectors will be:

$$N \geq \frac{299 \cdot 800}{7313} = 33\ \text{buc.}$$

The value of the additional resistance P is:

$$P = \mu \cdot P_{Rd}/2 = 0.5 \cdot 73.13/2 = 18.28\ \mathrm{kN}$$

If we take: N = 40, the force PR for a single connector will be:

$$P_R = \frac{L \cdot 1}{40} + \frac{P}{4} = 64.36\ \mathrm{kN} < P_{Rd} = 71.13\ \mathrm{kN}$$

The distance between connectors should be:

$$e < \frac{8000}{1 + N/2} = 381\ \mathrm{mm}$$

The scheme of the connectors arrangement is presented in Figure 6.

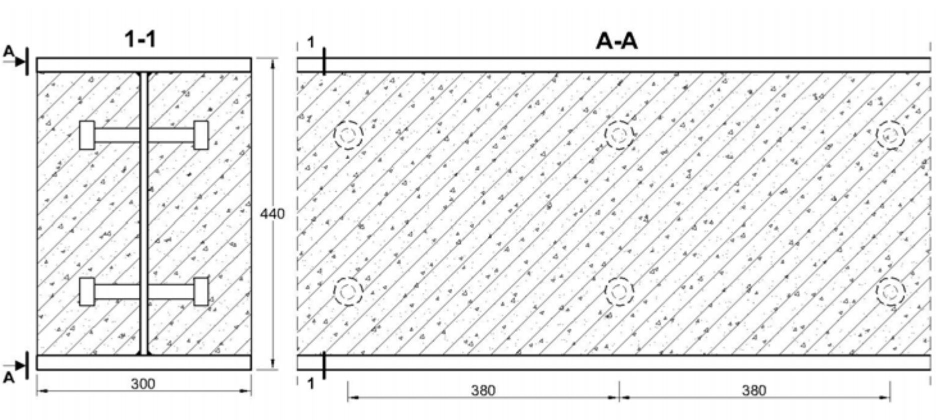


Fig.6

5. Conclusions

This paper presents an analytical method for the evaluation of the shear stresses over the interface between concrete and steel component for the composite columns of type concrete partially encased steel I-shape sections.

If the natural bond is not enough to achieve the required shear resistance, it is possible to use mechanical shear connectors, the widely used types being headed studs and the shot-fired nails.The numerical example, which is also given in the paper can be useful for the design of composite steel-concrete columns.

REFERENCES

[1] Bia,C., Ille,V.,Soare,M.V., *Rezistența materialelor şi teoria elasticității*.E.D.P.Bucureşti, 1983.
[2] Moga,C., *Stâlpi cu secțiune compusă oțel-beton.* Referat de doctorat. U.T.Cluj-Napoca, 2006.
[3] *** EUROCODE 2, *Design of concrete structures*. EN 1992.
[4] *** EUROCODE 3, *Design of steel structures*. EN 1993.
[5] *** EUROCODE 4, *Design of composite concrete and steel constructions*. EN 1994.

Ovidius University Annals Series: Civil Engineering Volume 1, Number **8**, Nov. 2006

Stability and Dynamic Problems in the Behaviour of Lightweight Structures

Ludovic KOPENETZ [a] Alexandru CĂTĂRIG [a] Pavel ALEXA [a]
[a] *Technical University Cluj Napoca, Cluj Napoca, 400027, Romania*

Rezumat: Începând cu anii 90' se constată importul masiv al unor construcții ușoare din Europa occidentală, având performanțe de „second hand". Pentru acțiunea de remontare pe amplasamente din România, de regulă, proiectanții se limitează la o activitate de reproiectare a fundațiilor, în funcție de terenul de fundare existent. Astfel, se acceptă că aceste structuri corespund cerințelor de siguranță şi confort în exploatare. În realitate, expertizele efectuate asupra unor astfel de structuri relevă necesitatea unor consolidări structurale atât pentru probleme de stabilitate cât şi pentru corectarea răspunsului dinamic din acțiunea vântului. În lucrare autorii prezintă problematica expertizării şi consolidării structurilor uşoare, în ceea ce priveşte stabilitatea şi rezistența la acțiuni statice şi dinamice, corelate cu aspectul economic implicat de aceste lucrări.

Abstract: Starting in the 90′, Romania experienced an important development in the lightweight structures use, most of them being imported from Western European countries, as ,,second hand" products. The relocation of these structures should involve a detaled design process, but - unfortunately - the current design activity is limited to the design of the foundation subsystem. The strength and stability requirements as well as those related to structural safety are implicitly supposed as being fulfilled. Several technical expertizes carried out by the authors on such erected structures revealed the necessity of strengthening/stiffening some structural elements or substructures in order to fulfil the code requirements regarding their stability and dynamic response experssed, mainly, in the wind induced displacements. The authors′ contribution is focused on the structural and economical aspects of the technical expertizes of these sructures viewing the strength/stability requirements versus financial involvemens.

Keywords: *lightweight structures, dynamic effect, wind loads.*

1. Introduction

The steel lightweight structures proved to be an efficient tool in the optimization of the material and human resources and, consequently, in achieving competitive economical solutions in the construction industry.

One visible results of the economical efficiency of the steel lightweight structures has been a massive import of ,,second hand" structures from Western Europe in Romania. It has to be stressed that the current Romanian legislation regarding the building licence requires a complex documentation which from the point of view of strength and stability is limited to a ,,foundation plan". As a consequence, many structural designers and structural design checkers limit the structural design process to the foundation technical solutions to accomodate the geotechnical requirements of the location site. Implicitly, the strength, stability, safety and serviceability requirements are supposed to be fulfilled.

Several technical expertizes of these structures recommended structural strengthening or stiffening, mainly, in order to correct their stability and dynamic response to wind action. Several collapses that took place during the last five years trigger an alarm signal for both, the structural designers and the beneficiaries. This is why the authors of the present contribution intend to present several aspects of the technical expertize, the redesign and design check activities of steel ,,second hand" lightweight structures acted upon by static and dynamic (wind induced) actions.

ISSN-12223-7221

2. Technical expertize and design check of steel lightweight structures

In the case of steel lightweight structures, the problems that regard the structural safety may be grouped in six classes:

- Problems regarding the quality of steel (yield, brittle fracture, lamelar teasing, etc.);
- Problems regarding the local and global stability (instability of flanges, of web of thin walled profiles, etc.);
- Problems regarding the fatique behaviour under cyclic actions;
- Buckling problems;
- Problems regarding the deformations induced by static and dynamic actions;
- Problems regarding the corrosion and erosion processes.

The steel lightweight structures are, as a rule, slender structures with complex structural makings and forms and, consequently, their stability is deeply dependent on their global geometry, i.e. on their initial equilibrium state involving the structural own weight, possible pretensioning and geometrical and material imperfections.

The structural design and technical expertize of these structures have to be conducted in the (geometrical) nonlinear domain involving all parameters that contribute to the structural instability.

A very specific phenomenon that is associated to this type of structures is the loss of global stability induced by the spreading of a local stability mode over the entire structure.

The SNAP type of instability has a strong dynamic effect character, which in its turn, is associated with high values of aceleration, therefore with high values of inertia forces.

For very low rise, almost flat structures ($f/l \cong 0.03 \div 0.06$), the SNAP type buckling induces accelerations with values up to $(10 \div 12)$ m/s^2.

The SNAP type loss of stability has been, also, present at lightweight structures not necessarily of low rise type. The case of the old roof of the ROMEXPO, Bucharest building having a rise of vault at key of 17.9 m and a diameter of 93.5 m ($f/l \cong 0.19$) that lost its stability via SNAP buckling is well known in this country. The SNAP phenomenon has been initiated by the superposition of gust of wind and local snow piling up but, it was made possible by the very flexible joint connections.

An important component of the technical expertize and design check activities is the computation of the drift, of the remanent drift, of the limit rotation capacity of bars and joints and the oligocyclic fatique strength.

Regarding the story drifts – involving the structural lateral stiffness, the fulfilment of the admissibility values of above mentioned parameters is decisive. The strength to oligocyclic fatique can be checked by computing the secondary stresses (produced by vibrations or by the dayly thermal contraction – extension phenomenon) taking into account the interval span of the stresses.

3. Loadings of steel lightweight structures

The main loadings of the steel lightweight structures are provided by their own weight (dead load), wind pressure, tempeature, induced vibrations and support settlements. These loads have to be separately analyzed taking into account the structure type and building importance class.

- Dead load

The design and/or the technical expertize of steel lightweight structures have to consider the following weight loads:

a) Active loads provided by the weight of meteoric water (in the case of accidental blocking of draining system), the weight of snow or of ice;
b) Inactive loads that include the weight of structural elements, the weight of isolation layers and other dead loads.

- Wind loads

The maximum value of the wind pressue has to be computed as the most severe combination of the interior and exterior pressure. The designer has to provide for any pressure accidental increase.

- Influence of ambient temperature

A low ambient temperature has to be taken into account. The sructural elements that are exposed to temperarures lower than 0^o will be loaded by the ice formed from athmospheric humidity. In the case of tubular structures, a low temperarture of the gas or the steam from the tubular will induce a decrease the interior pressure in the tube to such low values that the exterior pressure may create problems of tube wall resistance.

- Influence of dynamic effects

The structural vibrations may have damaging effects. The vibrations of the steel lightweight structures are produced by:

- impact forces;
- the resonance effect due to existing equipments or machinery, air-conditioning equipment, ventilation, music, dance, spectators applauses or vehicle trafic;
- the wind;
- the earthquake.

- Influence of thermal contraction – expansion

The termal temperature induced efects (contractions, expansions) have to be consideed in combinations with loadings due to other factors:

a) thermal loadings due to constraints (blockings). Fixed supports or anchorages will block the free thermal contraction – expansion developing a dangerous stress state in the structural elements.
b) In the case of several structural materials with different thermal expansion coefficients (steel aluminium), supplementary stresses are induced into sructural elements.

4. Problems regarding the flexibility of steel lightweight structures

A steel lightweight structure has to be flexible enough in order to prevent the following problems that may be caused by temperature variations, support settlements and other above mentioned factors:

- problems arising in the connecting zones of the structural elements;
- overloadings of the support zones;
- deteriorating the linking system of the shell with the structure.

The fulfilment of these requiemens can be achieved by:

- computation the maximum effective values of the displacements and their limiting to admissible values;
- computing the maximum gap of the stress spectrum and its limitation to the admssible values;
- limitation of the reaction values in the structure – equipment and structure – shell linking zones.

In the case of lightweight structures with large spans, high variations of displacements are possible and they are associated with high stress values. In order to reduce these associated stresses, initial or mounting displacemens (called counter – balance displacements) have to be introduced in the support zones or other parts of the structure. These displacements have to be added up with other displacements produced by the loadings. The maximum obtained values have to be smaller than the admissible values.

It has to be stressed that in the case of lightweight steel structures with an elastic linear behaviour, no stress concentrations take place. But in the case of structures with a nonlinear elastic behaviour, the stress concentraions could have dangerous effects on structural safety. In these cases, the plastic hinges induce deformations much larger than those produced in the elastic domain.

5.Problems of laboratory tests

The specificity of steel lightweight structures requies a minimum of laboratory testing. The folowing laboratory tests should be carried out:

- The test of axial stessing. This test is aimed at determinig the following parameters:

  - apparent yield limit;
  - ultimate stress limit;
  - axial deformation associated to ultimate stress limit.

- Brinell test (hardness test). A minimum number of three tests are necessary. For each print two diameters should be measured such that their difference is less than 2%.

- The test of bending under impact. This test requires 8 specimens with U form cuttings and 8 specimens with V form cuttings. The tested material will exhibit either a brittle or a viscous behaviour.

6. Ascertaining the life duration of the structure

The life duration expresses the time span over which a certain structural element will be able to support the associated loadings int specified conditions. The procedure for assesing the life duration is based on the history of loading process and on the histogrames of stress gauge $\Delta\sigma_i$ (measured or computed). Accepting the principle of linear adding up (Palmegren, Langer and Miner – PLM) the annual damage S_{an}, the life span D_v can be computed as

$$D_v = \frac{1}{S_{an}}$$

7.Steel lightweight structures of sandwich type materials

The sructures made up of sandwich type materials are highly efficient sructures due to several features that are possible only in this case:

- a large variety of forms;
- long life duration;
- favorable seismic behaviour;
- hgh termal isolation;
- very adaptable to any type of location and during any sezon of the year.

The first use of sandwich type materials, i.e. of layered or composite materials that couples the properties of each component material is dated back in the 60′. Due to the large number of different materials that may be combined, a large spectrum of sandwich type panels may be obtained and insert into the metal structure acting as a structural component.

The metalic layers with or without ribbs that make up the external faces of the composite panel are fabricated from steel or aluminium and have a thickness of 0.5 mm ÷1.5 mm.

The internal linking layer is made up of polymers of small density (ρ = 10 kg/m^3 ÷ 50 kg/m^3). The usual polymers that are used are polyuretan foam and polystiren with the thickness of 40 mm ÷100 mm.

The exterior layers will provide for the tension or compression stresses while the interior linking layer has to undertake shear stresses.

The technical xpertize and the design check of these sructures has to refer to the overall and local structural behaviour. The code requied safety has to be, also, checked.

For the „imported second hand” sandwich type structures, laboratory investigations are required. The laboratory test has to include the composite element and the component materials. The laboratory tests of the materials that make up the composite element are of the usual type.

The laboratory tests on the sandwich element has to reveal the linking between the exterior layers. The tests have to include:

- test of the tension strength;
- test of element in bending (static schemes are of cantilever type, two sides support, boundary support, etc.);
- test of shear srength;
- test of torsion strength.

In the case of composite elements without ribbs, the stiffness in bending of the exterior metalic layers may be neglected. In this case, the inertia moment of the composite element is given by:

$$I_{sandwich} = 2Bt\left(H - \frac{t}{2}\right)^2$$

where:

- *B* is the wide of the panel,
- *t* is the thickness of the exterior layer,
- *H* is the thikness of the composite panel.

The computation of the deformations due to shear force, the deformation of the web has to be aken into account since the displacements due to bending and shear, respectively, are of the same order of magnitude.

These requirements bring about computational difficulties and the MEF technique has to be applied with great care, otherwise, the obtained results have nothing to do with the real structure.

8.Concluding remarks

- The technical expertize of steel „second hand" lightweight structures is a very complex problem.

- The bearing capacity of the structure has to be computed in three steps (the transition from a step to the next one will be carried aut if the obtained results in the current step are not relevant). The steps should follow the bellow pattern:

Step 1. - Identification of the materials through physical and/or chemical analyses.
- Simplified static analysis including the checking of the connecting zones for fatique.

Step 2. - Static and dynamic analysis (including the static and dynamic stability) taking into account the spatial behaviour of the structrue.
- Computing the life span taking into account the future serviceablity loadings.

Step 3. - In situ testing (under static and dynamic loading regime) including the exact geometry computation using surveying techniques. During this step, the possible up rise vault bent have to be measured as well as the rectilinearity of the sructural elemens (beams, columns).
- In the case of lightweight high structures, (as are the mobile phone type equipments), the vibrations have to be depicted via dynamic surveying procedures.

9. References

[1] Cătărig, A., Kopenetz, L., Alexa, P., 1994, *Expertizing and Monitoring of R/C Structures in Corrosive Media*. Proceedings of the 10th International Conference on Experimental Mechanics, vol.2, Lisbon, pag.849-854.
[2] Kopenetz, L., 1992*, Structural Analysis of Mixted Light Structures*. Acta Technica Napocensis, nr.35, Cluj-Napoca, pag.75-86.
[3] Kopenetz, L., Kollo, G., 2003, *Glued Steel-Concrete Composite Structure*. International Conference of Civil Engineering and Architecture, Sumuleu, pag.157-160.
[4] Kopenetz, L., Cătărig, A., Mathe, Aliz, 2005, *Comportarea în situ a structurilor din oțel de tip offshore*. Revista construcțiilor, anul I, nr.1, Bucureşti, pag.76-77.
[5] Cătărig, A., Kopenetz, L., 1991, *Time Surveyance and in Situ Testing by Dynamic Methods of Steel Structures.* Proceedings of the 6th International Conference on Metal Structures, vol.3, Timişoara, pag.259-265.
[5] Cătărig, A., Kopenetz, L., Alexa, P., 1994, *Nonlinear Analysis of Static And Dynamic Stability Of Metallic Chimneys*. Thin-Walled Structures, Vol.20, pag.129-138.
[6] Cătărig, A., Kopenetz, L., 1993, *Elemente finite de frontieră.* Studii şi cercetări de Mecanică aplicată, nr.2, tom 52, pag.103-109.

[7] Cătărig, A., Kopenetz, L., 1991, *Structuri prefabricate pentru drumuri în condiții grele de fundare.* Revista Construcții, nr.4-5, pag.73-74.
[8] Kopenetz, L., 1991, *Nonlinear FEM Analysis of Cables and Membranes Structures*. Proceedings of the 6th International Conference on Metal Structures, vol.3, Timişoara, pag.156-161.

Present-Day Tendencies in Domotics

Carmen MÂRZA [a] Delia DRĂGAN [a]

[a] *Technical University Cluj Napoca, Cluj Napoca, 400027, Romania*

Rezumat: Lucrarea conține aspecte privind conceptul de casă comunicantă în contextul prezentării tendințelor actuale ale domoticii. Casa comunicantă se caracterizează prin faptul că toate echipamentele alimentate cu energie electrică sunt interconectate într-o rețea de comunicații, care permit asigurarea unui confort în concordanță cu pretențiile beneficiarilor, monitorizarea consumurilor şi managementul facil al acestora.

Abstract: The present paper details issues concerning the concept of smart home in the context of the present-day tendencies in domotics. The smart home is characterized by the fact that all the electrical power supplied equipment is interconnected in a communications network and provides the customer the required comfort, the monitoring of the consumptions and an easy management.

Keywords: *domotics, intelligent home, ecological home, smart home.*

1. Introductory notions

At the end of the 20th century, when new technologies were developed and implemented in households, a new concept also arose, that is today called DOMOTICS.

Domotics is defined as the total amount of facilities provided by advanced technologies together with computer sciences and telecommunications that increase the comfort of the habitat and services in a home. As a consequence of their implementation, a new system of interhuman relationships is established both among the family members and among them and society.

Among the functions fulfilled by domotics, one can enumerate:

- **the home technical management, meaning:**

→ the management of electricity, heating, ventilation/air conditioning, water;

→ control and programming of household appliances;

→ technical security and safety (signalling of damage);

- **family life management**:
  → health, monitoring of people with various problems (ill persons, children);
  → finances (payments) and means to work at home;
  → reservations;
  → shopping;
- **communications**: radio-television, interphone, telephone, e-mail;
- **culture, entertainment**: creating, getting informed (access to databases), access to the Internet, to education, in the distance learning system, for example.

A more accurate and pertinent retrospective concerning the dwelling resources for the last century, indicates that it was extremely dynamic that not even forecasts could predict it

The electric power use in the homes increased continuously, the same happened to the comfort requirement on behalf of the dwellers. The human who has created high technology has also become dependent upon the facilities offered by it, and also its user and victim too.

After the energy crisis of the 1970’s and convening that more than 30 – 40 % of the energy consumption in the world occurs in the building sector, the demand of identifying new energy sources and to rationally make use of them has become a stringent necessity.

The governments of various countries initiated national scale projects to monitor and rationalise the power consumption in various sectors, without affecting the comfort and demands of the users. New

ISSN-12223-7221

concepts have been defined in the field of building in view of the new events.

Thus, in the ’80s in the USA, under the aegis of The *National Research Centre* in the *National Association of Home Builders,* a large-scale project was initiated dealing with “ **the intelligent home**”

The intelligent home field encompasses a large variety of technologies and solutions, dependent upon the final destinations of the buildings: commercial, industrial, institutional or residential.

The facilities deriving from this concept vary due to the use of the environment that itself changes according to the buildings location (climatic area, building situation, orientation), climate and weather-related factors respectively, for long (seasons) or short (moment of the day) intervals.

Initially developed in the 1970’s in the industrial sector, in order to automate production processes and optimise the plant and equipment performance, the intelligent buildings concept was later on turned to residential and business sectors, too.

In the 1990’s, on the basis of some of the intelligent buildings notion, another concept was derived, i.e**. the ecological home**.

The “green” concept impressed due to the manner of ultimately putting to work the resources and potential of the area in which the building is sited and the attempt of creating an as natural as possible climate.

The ecological buildings usually present some “green areas” that contribute to the real and psychological comfort of the building inhabitants and avoid CO_2 emission absorption. Such buildings exhibit some general and specific features that have been approached by the authors in other papers too.

As mentioned earlier, the most representative architect of ecological buildings is *Sir Norman Foster*, whose works include: the rehabilitation of the Parliament in Berlin, the Commerzbank Tower of Frankfurt (1997), London City Hall (2002), 30 St. Mary Axe (2004).

A particular case of this concept is represented by the notion of **autonomous building** or sustainable housing, a more Bohemian concept, that aims to use only communications ways and telephones from the infrastructure provided by the local authorities, the rest of the facilities being provided and managed from own resources.

Of course, such concepts are an answer to the objective or subjective demands of the customers. The most recently heard of concept of **smart home**, that includes and goes beyond the intelligent building concept was introduced by *John Chambers* in 2000.

2. The smart home

2.1. Definition and objectives of smart homes

The smart home is the most representative and extravagant product of DOMOTICS. Apparently, are addresses a privileged layer of the society.

In fact, it is the symbol of the needs of modern society that makes man enjoy the spectacular technological developments while still being very safe. This concept is an answer to the demands of ubiquity of modern people.

The following will show how a smart home will meet the demands of domotics.

The average person is mainly preoccupied by the benefits brought by new equipment to **the technical management of the dwelling**, such as heating, ventilation, air conditioning, hot water preparation and lighting operation.

The essence of the theory of smart homes lies in the technologies control that enables the integration, automation and optimising of all services and equipment defining and serving the microclimate inside the buildings. Significant reductions in the maintenance expenses and savings in energy consumption are found.

There are more methods of controlling services in a building, and they can be summarised in two types:

- methods based on the time variable – function of seasons and moment of the day;
- methods based on basic parameters optimisation, such as the temperature of heating water and the heating of the heating system, the illuminance in the case of lighting plants, the temperature and humidity of the air conditioning plants etc.

In Romania the heating and electricity bills represent a problematic issue and it is for this reason that the authors would like to put an emphasis on the way in which the smart home controls such services.

HEATING

- The time control (on the basis of the time variable) is used to switch on and off the heating system during pre-established periods during the day, the week or even for longer periods of time, while still supplying the required temperature in the moment the habitat is dwelt in again.
- The temperature control (basic parameter) can be provided by:
  - equipping with radiator thermostatic valves, that feel the inner room temperature and adjust the heat flow passing through the radiator, convector, etc. on which they are mounted;
  - compensated systems – that will control the heat agent function of the outer temperature increasing the flow in the circuit when the outer temperature decreases, respectively its decrease when the outer temperature goes higher;
  - the continuous or interrupted installation operation, dependent upon the outer temperature is recommended when the temperature outside goes well below 0^oC, or when the system antifreeze protection is supplied by a continuous system running;
  - as an alternative to the antifreeze protection, the heat can be delivered in doses from an independent circuit together with other fluids (or gels) whose freezing temperatures are below that of the water;
  - other methods, including thermostats, infrared passive sensors or even equipment hand-adjusted methods.

ELECTRICAL ENERGY

- control based on the time variable:
  - the automated switching on and off of each zone in the building according to a schedule of light usage;
  - mounting some infrared warning sensors where only an intermittent presence occurs, so that the presence of people can be signalled;
- control on the bases of the basic parameter, that is of illuminance:
  - division of larger areas into smaller ones and their specific lighting according to the level of light needed;
  - monitoring the lighting level, that is keeping a balance between the natural and artificial light in order to provide the level of light that is necessary for each of the activities carried out;
  - electrical or electronic light variators enabling the adapting of the light intensity.

As for the **security functions** in a smart home, they exhibit mainly two specific features:
→ the technical security – eliminates the risks concerning defect occurrence, such as fires, water or gas leakage, short-circuits or overcharges in the electrical circuits and respectively defects remedies and warning sent to the home owner instantly (by the mobile phone, for instance or to the heating central;
→ providing the security against unwanted guests as presence and perimetral sensors can be implemented.

Not to mention the positive influence these security functions can induce to the human mental features.

The smart home enables the integration of all devices supplied by electrical energy in a communications network and its complete management and operation. Thus the consumption in each utility source can be monitored and the dweller can be warned in case consumption levels that can be accepted or afforded are exceeded.

The connection to such network can provide **information, communication services, access to culture** and **entertainments, electronic commerce means.**

Practically, the new technologies change our way of thinking about life, our life and our way of dealing with family and life matters.

2.2. Implementing means

In order to be functional, a smart home must have additional equipment as compared to a conventional home, in two aspects:

- it must be equipped with a central computer or server, to manage the peripherals with predefined functions;
- it must be wired in a specific manner.

The equipment can be connected in the network in more ways:

a) Power line Communication, with the two categories of power lines:

→ home power lines that drive household appliances and heating, air conditioning, ventilation, water, electricity, alarms and the related automation;
→ computer based power lines that authorise the transport of data and media.

Mention should be made that at present, research is carried out, in the domain of video power lines for the distribution of sound and image.

These power lines can exist in the support of the electric lines, because of the various frequencies they bear upon. However, their lack of reliability and lack of return way enabling only the command and not the surveillance of the devices represent a drawback.

b) The wireless solution means infrared or radio waves. This solution is often met, as more and more homes have remote controls for this purpose. Problems are represented by the short range of the infrared controls and the jamming by metal barriers of the radio waves.

c) The wired solution makes possible the centralisation of the controls in a wired infrastructure with the UTP cable (Unshielded Twisted Pairs) that enables the network connection of the elements to be guided, the execution elements, the computerised and audio-video equipment.

Technically, they disturb, but the perturbations are minimum and do not induce communication errors.

3. Conclusions

The smart home includes last generation technologies in the technical field. As the life cycle of the new – electronic and informatics – technologies is generally short, a smart home must always be open to developments in the digital world.

Such an attitude represents a possible alternative to the people's requirements for comfort when the energy resources are still limited.

The selection of one of the types of homes from the list shown above is very subjective, depending upon the people's bias towards a more the natural habitat or towards a very updated technology-based living. Evidently, the solutions also have a financial aspect.

As expected, the Microsoft founder's home, Bill Gates, was defined as the symbol of the smart home.

Finally, the main features of a smart home can be summarised in the following:

- **the evolutionary feature –** when choosing such a solution, the extraordinary mobility of technologies and the means of implementing new ones in the former framework must be considered;
- **the autonomy –** due to the high level of automation, the smart home finds and remedies the possible disorders as the transducers and equipment will communicate the date related to such events to the central server;
- **the security –** the smart home provides a high level of security and safety, both technically (defect remedies) and from the guarding point of view;
- **the economisation –** the initial investment is quite high due to the technological equipment to be included and to the idea of comfort for the dweller behind the concept, but, in the long run, automation and low time consumption in the access to information can become a source of saving resources.

4. Bibliography

[1] Buzdugan, M., I., *Casa comunicanta si confortul ambiental*, 2006, Conferinta Stiinta Moderna si Energia, Cluj-Napoca;
[2] Chioreanu, C., *Domotica – Realitate si Scop*, 1994, Revista Instalatorul, nr. 3/94, Bucuresti;
[3] Mills, G., *Code and Design 1995-2006*, Alan Chapman Edit, 2004.

Conf. Dr.ing.Carmen Mârza ,
E-mail: marzacar@bavaria.utcluj.ro
Conf. Dr.ing. Delia Drăgan,
E-mail: Delia.Dragan@cfdp.utcluj.ro

Concrete – Filled Steel Rectangular Section Columns. Shear Connection Design

Cătălin MOGA [a] Ştefan I. GUŢIU [a] Cristina CÂMPIAN [a] Gabriel URIAN [a]
[a] *Technical University Cluj Napoca, Cluj Napoca, 400020, Romania*

Rezumat: În lucrare se prezintã o metodã analitica pentru evaluarea eforturilor de lunecare la interfaţa dintre oţelul structural şi miezul de beton în cazul stâlpilor cu secţiune compusã oţel-beton, realizaţi în soluţie constructivã de tuburi metalice rectangulare umplute cu beton. Este inclus un exemplu numeric de calcul.

Abstract: This paper presents an analytical evaluation method for the longitudinal shear stresses over the interface between the structural steel and the concrete filled steel tubular section. A working example is also given in this paper, which can be useful in the design activity of such type of structures.

Keywords: *composite columns, concrete filled tube, shear connection.*

1. Introduction

Where composite columns of the type concrete filled rectangular hollow sections are subjected to significant transverse shear, provision shall be made for the transfer of the corresponding longitudinal shear stress at the interface between steel and concrete.

If the *natural bond* (adhesion, interface interlocking and friction) is not enough to achieve the required shear resistance, the mechanical connectors will be used.

Shear connectors should be provided, based on the distribution of the design value of longitudinal shear, where this exceeds the design shear strength τ_{Rd} , given in Table 1.

Table 1

CROSS-SECTION TYPE	τ_{Rd} (N/mm^2)
Concrete filled circular hollow section	0.55
Concrete filled rectangular hollow section	0.40

2. Longitudinal shear stresses

To determine the longitudinal shear at the interface between concrete and steel, the filled concrete, Figure 1, is transformed into an equivalent steel section, Figure 2.a, using the modular ratio n.

The equivalent in steel width of the concrete, Figure 2.a, will be::

$$t_e = b_c / n \tag{1}$$

where the modular ratio can be taken as:

$$n \approx 2 \cdot n_i = 2 \cdot E_a / E_{cm} \tag{2}$$

E_a - modulus of elasticity of structural steel;
E_{cm} – secant modulus of elasticity of concrete.

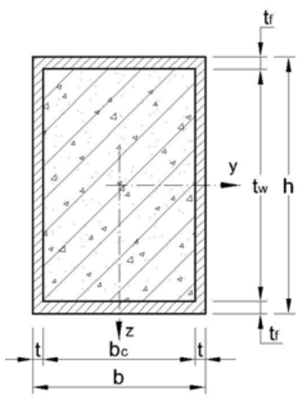


Fig.1

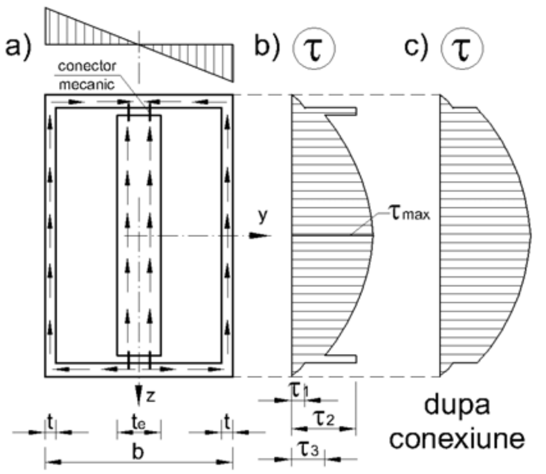


Fig.2

In the case of the columns of type concrete filled rectangular hollow steel section, in the absence of connection at the interface between steel and concrete, the shear stresses in accordance with Juravsky formula, Figure 2.b, will be:

$$\tau_1 = \frac{V_{Sd} S_a}{b \cdot I} \tag{3.a}$$

$$\tau_2 = \frac{V_{Sd} S_a}{2t \cdot I} \tag{3.b}$$

$$\tau_3 = \frac{V_{Sd} S_a}{(2t + t_e) \cdot I} \tag{3.c}$$

$$\tau_{max} = \frac{V_{Sd}(S_a + \frac{1}{n} S_c)}{(2t + t_e) \cdot I} \tag{3.d}$$

where (Fig. 3):

- S_a – section modulus of the steel component referred to neutral axis y-y:

$$S_a = bt_f\left(\frac{h_w + t_w}{2}\right) + 2t\frac{h_w^2}{8} \tag{4}$$

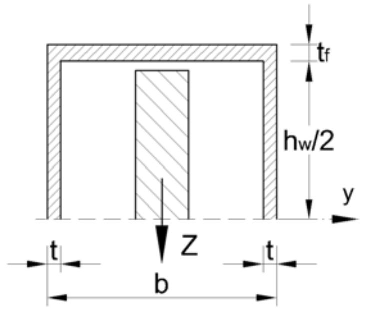


Fig.3

- S_c – section modulus of the concrete referred to neutral axis y-y:

$$S_c = b_c \frac{h_w^2}{8} \tag{5}$$

- I – moment of inertia of the equivalent in steel of the entire cross-section:

$$I = I_a + \frac{1}{n} I_c \tag{6}$$

The longitudinal shear force between steel and concrete will be:

$$L = (\tau_2 - \tau_3)\, t_e = \Delta\tau \cdot t_e \tag{7}$$

By replacing the shear stresses values τ_2, τ_3 into eq. (7) it results:

$$L = \frac{V_{Sd} S_a}{I}\left(\frac{1}{2t} - \frac{1}{2t + t_e}\right) t_e = \frac{V_{Sd} S_a}{I} \frac{t_e^2}{2t(2t + t_e)} \quad [F/L] \tag{8}$$

The average shear stress at the interface between steel and concrete is:

$$\tau_F = \frac{L}{\sum b_i} \quad [F/L^2] \tag{9}$$

where:

$$\sum b_i = b_c + 2\frac{h_w}{2} = b_c + h_w$$

is the half perimeter of the contact surface between steel and concrete.

If: $\tau_f > \tau_{Rd}$, the natural bond is not enough to achieve the shear resistance and will be necessary to use mechanical shear connectors.

The number of the mechanical shear connectors for the entire length *l* of the column results from the condition:

$$N \geq L\frac{1}{P_{Rd}} = \frac{V_{Sd}S_a}{I}\frac{t_e^2}{2t(2t+t_e)}\frac{1}{P_{Rd}} \qquad (10)$$

3. Working example

The connection for a composite column of type concrete filled rectangular hollow steel section is designed.

Materials and characteristics:

Box section - Steel: S 355
- f_y=355 N/mm^2
- E_a= 210 000 N/mm^2

$$I_a = \frac{25 \cdot 40^3}{12} - \frac{22 \cdot 37^3}{12} = 40\,470 \text{ cm}^4$$

Concrete - Class: C 25/30:
- f_{ck} = 25 N/mm^2
- E_{cm} = 30 500 N/mm^2

$$I_c = \frac{22 \cdot 37^3}{12} = 92\,864 \text{ cm}^4$$

Connectors: headed welded studs:
- d = 19 mm; h= 100 mm
- f_u = 450 N/mm^2
- $\gamma_v = 1.25$

Design data (Figure 4)

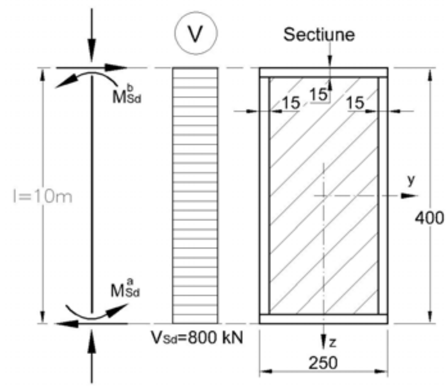


Fig.4

Connection design

The mechanical design model is presented in Figure 5.

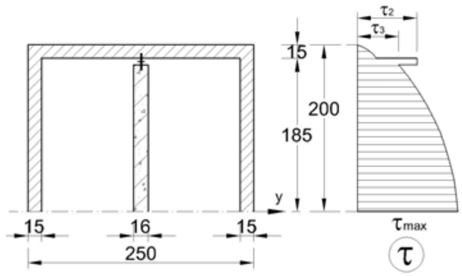


Fig.5

It results:

S_a = 25·1.5·19.25+2·1.5·18.5^2/2=1235 cm^2

$$I = I_a + \frac{1}{n}I_c = 40\,470 + \frac{1}{13.8}92\,864 = 47\,200 \text{ cm}^4$$

where:

n = 2·n_i =13.8

$$n_i = \frac{E_a}{E_{cm}} = \frac{210\,000}{30\,500} = 6.88$$

The longitudinal shear force will be:

$$L = \frac{V_{Sd} S_a}{I} \frac{t_e^2}{2t(2t + t_e)} = 388 \text{ daN/cm}$$

where: $t_e = 22/13.8 = 1.6$ cm

The adhesion-friction stress over the interface between concrete and steel is:

$$\tau_f = \frac{L}{\sum b_i} = 0.66 \text{ N/mm}^2 > \tau_{Rd} = 0.40 \text{ N/mm}^2,$$

so it results that are necessary mechanical connectors,

where:

$$\sum b_i = 2 \cdot 18.5 + 22 = 59 \text{ cm}.$$

The design shear resistance of a headed stud automatically welded, in accordance with EC 4, is:

$$P_{Rd} = \min \begin{cases} \dfrac{0.8 f_u \pi d^2 / 4}{\gamma_v} = 81.65 \text{ kN} \\ \dfrac{0.29 \alpha d^2 \sqrt{f_{ck} \cdot E_{cm}}}{\gamma_v} = 73.13 \text{ kN} \end{cases}$$

The number of connectors will be:

$$N \geq \frac{388 \cdot 1000}{7313} = 53 \text{ buc.}$$

For two rows of connectors the maximum distance between these will result:

$$e = \frac{10000}{1 + N/2} = 385 \text{ mm}$$

The proposed arrangement of the headed stud connectors on the composite cross-section is presented in figure 6.

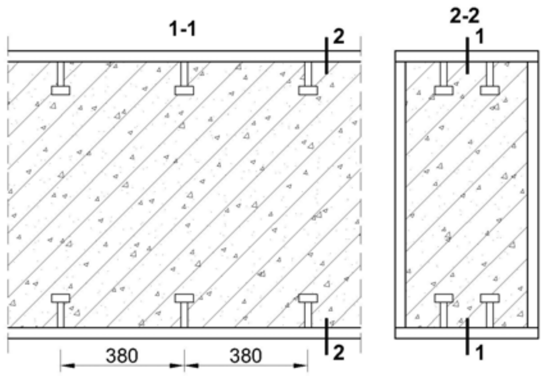


Fig.6

4. Conclusions

This paper presents an analytical method for the evaluation of the shear stresses over the interface between concrete and steel component for the composite columns of type concrete filled rectangular hollow steel section.

If the natural bond is not enough to achieve the required shear resistance, it is possible to use mechanical shear connectors, the widely used types being headed studs.

The numerical example which is also given in the paper can be useful for the design of composite steel-concrete columns.

5. References

[1] Bia,C., Ille,V.,Soare,M.V., *Rezistența materialelor și teoria elasticității*.E.D.P.București,1983.

[2] Moga,C., *Stâlpi cu secțiune compusă oțel-beton.* Referat de doctorat. U.T.Cluj-Napoca, 2006.

[3]*** EUROCODE 2. *Design of concrete structures*. EN 1992.

[4]*** EUROCODE 3. Design of steel structures. EN 1993.

[5] *** EUROCODE 4. Design of composite concrete and steel constructions. EN 1994.

Circular Composite Columns. Mechanism of Shear Transfer

Petru MOGA [a] Vasile PĂCURAR [a]
[a] *Technical University Cluj Napoca, Cluj Napoca, 400020, Romania*

Rezumat: În lucrare se prezintă mecanismul de transfer a eforturilor tangenţiale la interfaţa dintre tubul circular de oţel şi miezul de beton în cazul stâlpilor cu secţiune compusã oţel – beton, realizaţi în soluţie constructivã de tuburi metalice circulare umplute cu beton. Este prezentat un exemplu numeric de calcul a eforturilor longitudinale de lunecare.

Abstract: The mechanisms of the shear transfer over the interface between the circular steel tube and the concrete core as well as the design of the shear connection are presented in this paper. A numerical example for the evaluation the longitudinal shear stresses over the interface between structural steel and concrete is also presented here.

Keywords: *composite columns, shear stresses, shear transfer, connection.*

1. Introduction. General remarks

A composite column may either be concrete partially or completely encased section or a concrete-filled section, Figure 1.

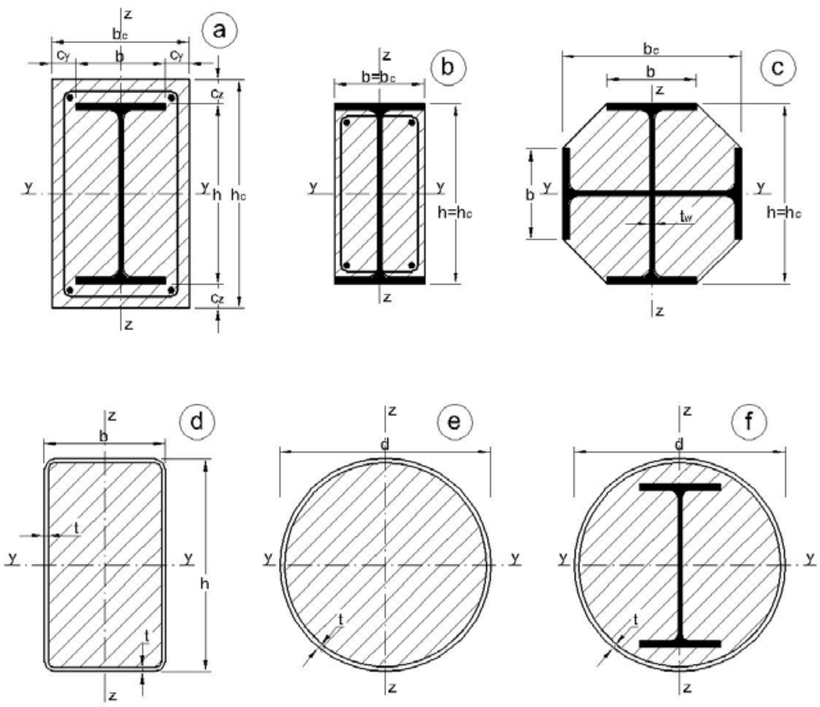


Fig.1. Composite columns

ISSN-12223-7221

In case of the concrete-filled hollow steel sections, there are three mechanisms which are often referred to as the natural bond, by which shear stresses can be transferred over the interface between the steel tube and the concrete core, these are: adhesion, interface interlocking and friction, Figure 2.

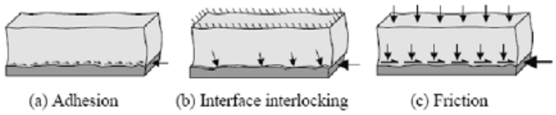


Fig.2

If the natural bond is not enough to achieve the required shear resistance there is the possibility of using mechanical shear connectors, the most widely used types being headed studs and the shot-fired nails.

The shear stresses, which take place on the interface steel-concrete, are shown in Figure 3.

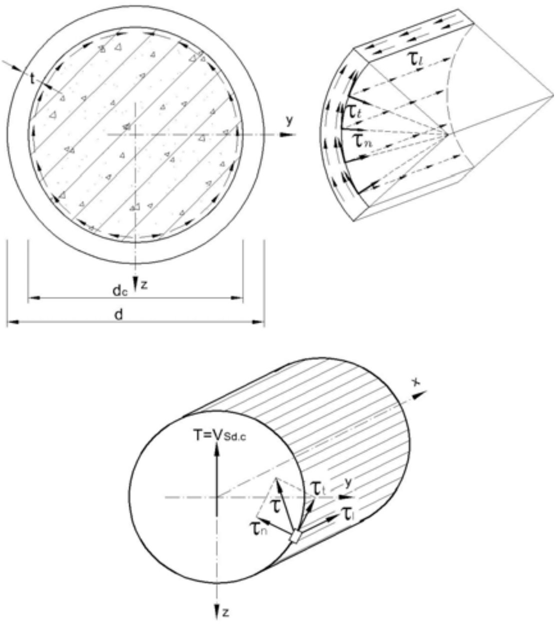


Fig.3

Taking into account that the structural steel and the concrete have different mechanical characteristics, the concrete core is transformed into an equivalent steel section using the modular ratio *n*. The mechanical model is presented in Figure 4.

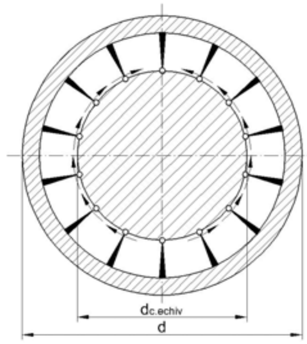


Fig.4

The equivalent in the steel area of the concrete core will be:

$$A_{c.echiv} = A_c / n \quad (1)$$

where the modular ratio can be taken as:

$$n \approx 2 \cdot n_i = 2\frac{E_a}{E_{cm}} \quad (2)$$

2. Tangential stresses

The state of tangential stresses caused by the shear force $T=V_{Sd.c}$ is presented in Figure 5, where τ_{xz} is the shear stress given by the Juravski formula:

$$\tau_{xz} = \tau_{zx} = \frac{TS_y}{bI_y} \quad (3)$$

where:

- S_y – section modulus of the slipping portion referred to neutral axis:

$$S_y = \frac{2}{3}\sqrt{\left(R^2 - z^2\right)^3} \quad (4)$$

- b – width of the section at the distance z from the neutral axis:

$$b = 2\sqrt{R^2 - z^2} \quad (5)$$

- I_y – moment of inertia of the cross-section:

$$I_y = \frac{\pi R^4}{4} = \frac{\pi D^4}{64} \quad (6)$$

By replacing the above parameters it results:

$$\tau_{xz} = \frac{T(R^2 - z^2)}{3I_y} \quad (7.a)$$

$$\tau_{xz} = \frac{4}{3}\frac{T}{A}\left(1 - \frac{z^2}{R^2}\right) \quad (7.b)$$

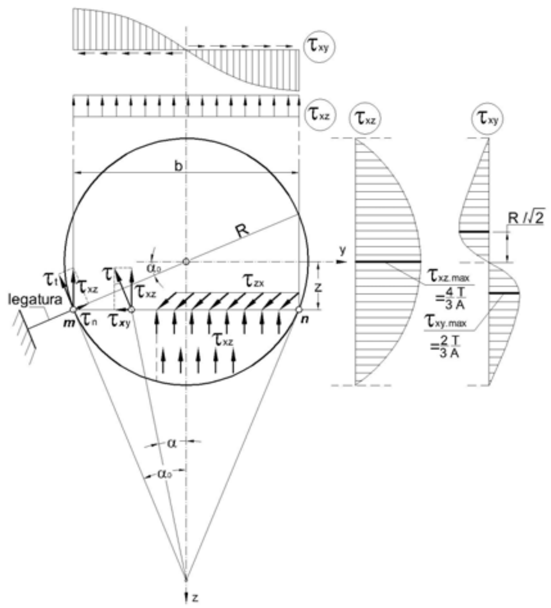


Fig.5

3. **Longitudinal shear between steel and concrete**

The longitudinal shear stress τ_l, equal with the normal component τ_n, of the shear stress τ_{xz}, will be:

$$\tau_n = \tau_l = \tau_{xz} \sin\alpha_0 = \frac{4}{3}\frac{T}{A}\frac{1}{R^3} z(R^2 - z^2) \qquad (8)$$

The maximum values of τ_l and τ_n is obtained from the condition:

$$f'(z) = 0 \quad \Rightarrow z = \frac{R}{\sqrt{3}}$$

It results:

$$\tau_{n.max} = \frac{8}{9\sqrt{3}}\frac{T}{A} = 0.51\frac{T}{A} \qquad (9)$$

The longitudinal and the normal shear stresses variation are presented in Fig 6.

The sum of τ_n divided by a quarter of the interior surface of the steel tube will give the value of the longitudinal tangential stress on the interface between steel pipe and concrete core:

$$\tau_f = \frac{4\sum \tau_n}{2\pi R_c} = \frac{4\left(\frac{2}{3}R \cdot \tau_{n.max}\right)}{2\pi R_c} = \frac{689 \cdot 10^{-4} \cdot T}{R_c R} \qquad (10)$$

where:

-R_c - the interior radius of the steel tube;

-R - the radius of the concrete core taking into account the modulus ratio and results from:

$$A_{c.echiv} = \frac{\pi R_c^2}{n} = \pi R^2 \quad \Rightarrow R = \frac{R_c}{\sqrt{n}} \qquad (11)$$

By replacing the value R in (9) it is obtained:

$$\tau_f = 689 \cdot 10^{-4}\frac{\sqrt{n}}{R_c^2}T = 0.275\frac{\sqrt{n}}{d_c^2}T \qquad (12)$$

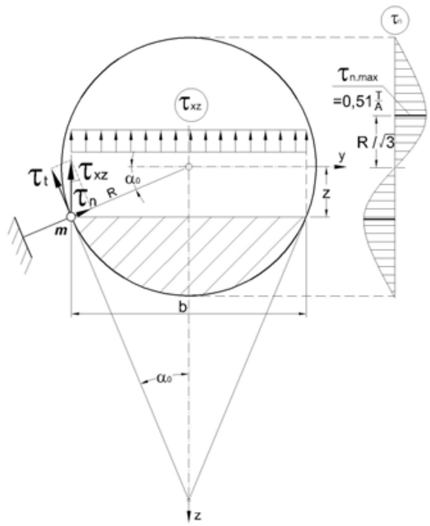


Fig. 6

The longitudinal shear force for the entire length of the composite column and respectively for a half of cross-section, will be given by:

$$L_l = \tau_f \frac{1}{2}\pi d_c \cdot l = 0.43\frac{\sqrt{n}}{d_c}T \cdot l \qquad (13)$$

If the natural bond is not enough to achieve the shear resistance, it will be necessary to use mechanical shear connectors and their number will result from the condition:

$$N \geq \frac{2 \cdot L_l}{P_{Rd}} \qquad (14)$$

In accordance with Eurocode 4, the design value of the longitudinal shear strength τ_{Rd} in case of a concrete filled circular hollow sections is τ_{Rd} =0.55 N/mm^2.

From the relation (13) the maximum value of the shear force when it is not necessary to use mechanical shear connectors will result:

$$T_{max} = 2\frac{d_c^2}{\sqrt{n}}$$ (results T in [N] for d_c in [mm]) (15)

It is necessary to underline that the shear force T represents the part of the shear force, taken over by the concrete component of the composite column, which can be evaluated with the relation:

$$V_{Sc} = V_{Sd}\frac{A_{cv}}{A_{av} + A_{cv}} = V_{Sd} - V_{Sa} \quad (16)$$

where:

$$A_{av} = \frac{2}{\pi}A_a \quad \text{and} \quad A_{cv} = A_{c.echiv} = \frac{A_c}{n}$$

4. Numerical example

For a composite steel-concrete column the longitudinal shear stress over the interface between the circular steel tube and the concrete core is evaluated.

4.1. Design data

Composite column cross-section and loading (Fig.7)

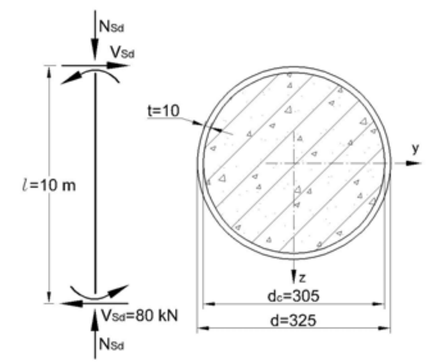


Fig. 7

Cross-section characteristics:

Circular pipe: 325 × 10 mm

Steel: S 355:

- f_y=355 N/mm^2
- E_a= 210 000 N/mm^2
- A_a=99 cm^2

Concrete: C 25/30:

- f_{ck} = 25 N/mm^2
- E_{cm} = 30 500 N/mm^2

$A_c = 731\,cm^2$

4.2. Longitudinal shear

Modulus ratio n:

$$n = 2 \cdot n_i = 2\frac{E_a}{E_{cm}} = 13.8$$

Equivalent in steel area of the concrete core:

$$A_{c.echiv} = \frac{731}{13.8} = 53\,cm^2$$

Shear force of the concrete component:

$$A_{av} = \frac{2}{\pi}A_a = \frac{2}{\pi}99 = 63\,cm^2$$

$$V_{Sc} = 80\frac{53}{63+53} = 36.55\text{ kN}$$

The shear force, which can be achieved by the natural bond:

$$T_{max} = 2\frac{d_c^2}{\sqrt{n}} = 50\text{ kN} > V_{Sc} = 36.55\text{ kN},$$

so it results that are not necessary mechanic shear connectors.

The longitudinal shear stress:

$$\tau_f = 0.275\frac{\sqrt{n}}{d_c^2}T =$$

$$= 0.40\text{ N/mm}^2 < \tau_{Rd} = 0.55\text{ N/mm}^2$$

5. Conclusions

The method to design the longitudinal shear connection between the circular steel tube and the concrete core, which is presented in this paper, is very simple and easy for applying in the design activity.

The presented method is one originally method, based on the elasticity theory, so experimental tests are useful.

6. References

[1] Bia C., Ille V.,Soare M.V., *Rezistența materialelor şi teoria elasticității.* E.D.P.Bucureşti, 1983.
[2]*** EUROCODE 2. *Design of concrete structures.* EN 1992.
[3]*** EUROCODE 3. *Design of steel structures.* EN 1993.
[4]*** EUROCODE 4. *Design of composite concrete and steel constructions.* EN 1994.

The Calculations of Precast Concrete Tank Foundation on Elastoplastic Subsoil

Marek WYJADŁOWSKI [a]

[a] *Wrocław Technical University, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław*

Rezumat: Regula de curgere a apelor de ploaie ci combinate cu apele uzate prin sistemul de canalizare la drenarea apelor uzate prin rețeaua de canalizare a fost realizat pe mai mulți ani folosind rezervoarele pentru înmagazinarea periodică a apelor uzate în exces. Rezervoarele din beton sunt frecvent folosite în ingineria civilă. Modelele pe mediul elastoplastic sunt folosite la proiectare rezervoarelor şi calculul forțelor interne în elementele de beton

Abstract: The regulation of rainwater and combined-wastewater flows through sewage systems at the stage of wastewater drainage through sewage networks has been realised for many years with the use of reservoirs for periodic storage of wastewater excess. Concrete storages are often used in civil engineering. The elastoplastic ground models are used by design of storage and calculation of internal forces in concrete units and theirs locks.

Keywords: *tank foundation, foundations on elastoplastic subsoil.*

1. Introduction

Storage reservoirs serve the periodic gathering of wastewater excess, unload the canalisation network and regulate the efflux to sewage treatment plants. System precast concrete tanks are used as combined-wastewater tanks, rainwater, storage and anti-fire reservoirs, etc. The advantages of the precast concrete tank system result from its fast assembly, simple material quality inspection and the possibility to control the leaktightness right after the tank has been assembled. Time saving in the precast concrete tank construction, in comparison with the monolithic tanks, stems from the short time needed for the assembly, as well as for groundwater drawdown [5], [7].

2. The characteristics of a selected precast concrete tank system

The precast concrete tank system will be represented here by the system produced by the DYWIDAG AG company. The basic elements ofthe systems are: U-type prefabricated units (see Fig. 1a), end-line tank prefabricated units (U-type, with a lateral wall (see Fig. 1b) and tank copingstones.

Prefabricated units are made of B30 – B45 concrete and typically reinforced with the steel of f_d = 500 MPa, in accordance with the DIN 1045 norm. The selection of a proper concrete and steel class depends on the individual exploitation parameters, geotechnical conditions, the depth of tank foundation, and others. The manner in which the prefabricated units are connected is a specific, patented technique. Reinforced concrete units are combined with the use of DYWIDAG system fast joints. In the wall chase on the surface combining U-type prefabricated units (see Fig.2.) and the tank coping stone, a rubber gasket is applied. Its diameter is 35 mm and it runs along the joint of prefabricated units. The tank elements are combined by the DYWIDAG system locks (see Fig. 2.), bolted with the high-resistance screws. The rules for the calculation of the tank foundation and the precast concrete tank construction on the elastoplastic subsoil will be presented on the example of a selected system U-type tank units attain spatial stiffness after they have been bolted with turn buckles seated at a

ISSN-12223-7221

uniform distance along the contact surface of the units and the circumferential gasket. Once the prefabricated units have been bolted, the gasket undergoes deformation to the thickness of about 10 mm, and the walls of the units touch one another.

a b

Fig. 1. Prefabricated unit: a) U-type, b) end unit

a b

Fig. 2. Prefabricated unit lock: a) locks at the wall, b) lock and wall chase

U-type tank units attain spatial stiffness after they have been bolted with turnbuckles seated at a uniform distance along the contact surface of the units and the circumferential gasket. Once the prefabricated units have been bolted, the gasket undergoes deformation to the thickness of about 10 mm, and the walls of the units touch one another. The copingstones are fastened to the vertical walls of the

U-type elements with the use of reinforcement bars cemented in vertical holes. The tanks are assembled on a foundation plate, which ensures the preservation of the designed levels of tank foundation and fall.

When a larger stiffness and leaktightness is required, the copingstones are fastened with the use of locks and bolts. Finishing works inside the tank, which include, among others, the cementation of the locks, are carried out in temperatures above 5^{o} C. The tanks are typically equipped with ventilation, sensor set, safety ladders, manhole covers, staircase landings, and others, like for example wash-away chamber or water/wastewater pumping station. Inside, the tank is covered with resins to protect the walls against aggressive sewage, petroleum-derivative substances, acids and bases. The prefabricated unit system offers the possibilities to construct a variety of objects: small technological chambers, single tanks – up to 100 m long, or multi-chamber tanks. In Poland the tanks with the cubic capacity up to 5000 m^3 have been constructed so far. Whenever the tank foundation level is designed below the ground water level datum, it is indispensable to test the limiting state of the load capacity of ground water uplift pressure. In calculating of total weight one has to take into account the weight of an empty tank and of the backfilling ground above the tank. When that condition is not fulfilled, additional loading of the tank is designed: concrete anti-displacement belts [5].

The requirements of the DYWIDAG prefabricated unit system restrict the forces that occur in the joints to tensile forces with the value of F=180 kN and allow for the tank settlement by less than s=10 mm. System joints of prefabricated units do not transfer bending moments. The bending moments in element jointing section are transferred by: the concrete in the compression zone, and the bolts fastened in the prefabricated unit locks in the tension zone. On the basis of calculated internal forces the following are possible: the determining of the number of the locks, then joint safety control and the computation of longitudinal reinforcement of tank prefabricated units according to [6], [11].

4. Stages in tank calculations

The exact tank calculation requires 3D-modelling in the MES programme [3], [8]. In case of complex, inhomogeneous geotechnical conditions [1], [2], tank foundation at the large depth or multi-chamber tank foundation, it is advisable to pursue a precise problem solution. As far as typical engineering problems are concerned,

the calculations may be done separately for the longitudinal section and cross-section of the tank. The calculations of the tank longitudinal section are carried out in the same manner as for the beam on elastic subsoil. Those calculations lead to the marking of the subsoil reaction r(x) under the tank and the internal forces M(x), N(x), T(x), where x stands for the coordinate assumed along the tank length L.

At the stage of the internal forces calculation in cross-section with B-width, the tank base slab is loaded with the evenly distributed subsoil reaction, side walls – with the earth pressure, ground-water pressure, the water pressure inside the tank; and the coping stone – with the subsoil and surcharge load. It is assumed that there is a jointed clamping of the coping stone and the vertical walls of U-type units.

Due to limited displacement of tank walls and their large stiffness, we assume intermediate earth pressure [10], assuming earth pressure ratio on the sidewalls – K, according to the formula (1):

$$K = \frac{K_0 + K_a}{2} \tag{1}$$

where: K_0 - coefficient of earth pressure at rest,
K_a - coefficient of active earth pressure.

5. Determination of tank stiffness

Preliminary selection of the sections of prefabricated units takes place basing on the experience of the tanks, which have been already carried out. The differentiation in calculating the beam stiffness occurs due to the way in which the tank copingstones are fastened. If the jointing is executed with the use of DYWIDAG system fast joints, in calculations one has to assume the stiffness of the whole tank cross-section. The whole tank cross-section transfers internal forces. When the tank precast coping stones are not clamped together with bolts, the joint does not transfer internal forces, and the computations are carried out as in the case of the beam whose stiffness at the prefabricated unit jointing point is reduced to the stiffness of the U-type unit. The differentiation of tank stiffness may be essential in its end segments, if system tops are designed, fastened stiffly to the tank, which increase the end segment stiffness.

6. Tank construction loads

Tank load consists in: tank dead weight, the weight of the liquid inside the tank, ground above the tank and the load on the surcharge. The loads distributed evenly along the tank length cause neither non-uniform settlement, bending moments, or shearing forces in sections. The stresses in the soil coming form evenly distributed load are summed up with the stresses from concentrated loads. Vertical loads affecting the tank are modelled as concentrated forces, and applied to the beam on the elastic subsoil. The chambers integrated with tank end units, manhole covers and technological equipment inside the tank contribute to the concentrated loads of the tank. In calculations the variants of an empty and filled tank are considered.

7. Calculation of the prefabricated concrete storage tanks on the elastoplastic subsoil

In engineering technology subsoil is normally modelled as one-parameter linear elastic. Linear elastic models of subsoil make it easy to calculate analytically inner forces in a storage tank while the subsoil is stratified and it is homogeneous on the whole length of the tank. What is more, symmetry of the load makes the task easier.

Constant geotechnical parameters under the foundation and symmetry of the load are assumptions, which are definitely hard to achieve for real long tanks.

In case of variable geotechnical parameters under the foundation of the tank and the asymmetrical load, calculations tend to be more complex. It is practical to use numerical methods, for example MES. While using the Coulomb Mohr's or Hardening Soil's models it is possible to describe soil as linear elastic or elastoplastic. Modelling in MES let us consider elastoplastic work, which is done by concrete tank. For every storage reservoir the useful load is put quickly, so calculations must be done in the same way as it is practiced for "undrained" soils. However, numerical modelling of the storage tank which takes into account the spatial cooperation of the tank with medium soil requires the use of 3D programs [3], [8]. Unfortunately these programs are not in common use among the architects yet. That is why it is suggested to proceed the following stages:

Stage 1: The simplified presentation of the tank as a substitute beam where bending and torsional rigidity is an equivalent of parameters of concrete storage tank's intersection.

Stage 2: Calculating the inner forces in a cross-section of a tank.

While modelling the Stage 1 it is important to consider the level of foundation concrete storage which is below the level of a surrounding area. The position of a substitute beam which is dependant on the position of a tank is presented in a Fig. 3

The solution is values of inner forces and dislocations on the whole length of a beam. The solution is values of inner forces and dislocations on the whole length of a beam. Solution is presented in a Fig. 4, 5.

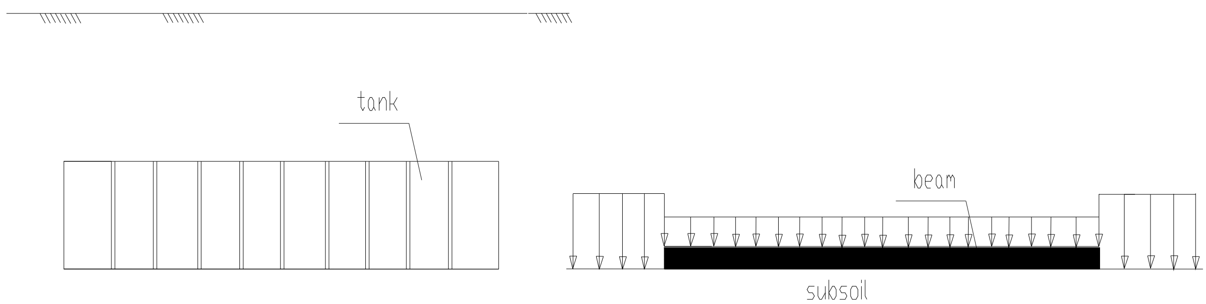


Fig. 3. The position of a substitute beam which depends on the position of a tank

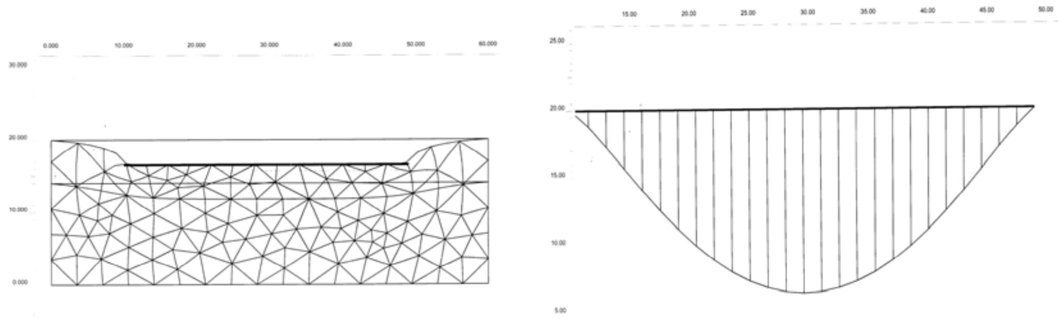


Fig. 4. Deformed mash and moments in a storage tank on a homogeneous subsoil and at symmetry of the load

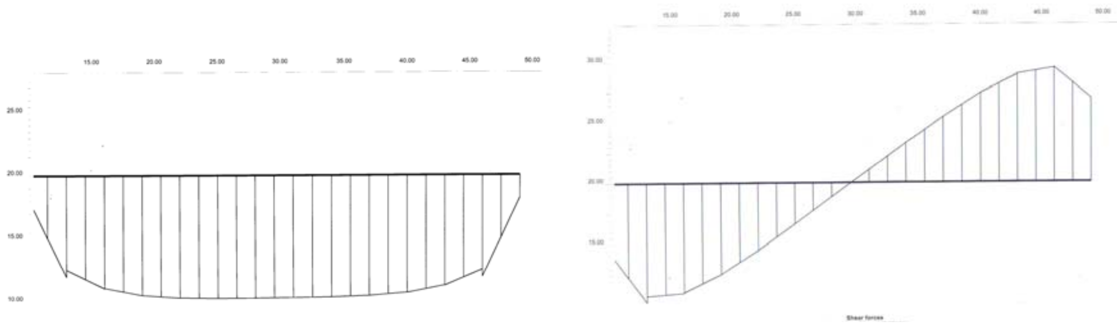


Fig. 5. Axial forces and shear forces in a storage tank on a homogeneous subsoil and at symmetry of the load

It was assumed in an example that the rigidity of a substitute beam was constant which means connecting all walls, foundation and the closure heads of all segments by the use of screws and locks. While connecting only walls and the foundation the rigidity is going to be variable on the whole length of the tank. It is hard to estimate precisely size of the zone where the rigidity is less at the segments' connections. Assuming that the beam is very short and its rigidity is less may cause a lot of problems in numerical calculation.

6. The numerical example

In the following example the prefabricated concrete storage is founded on an erratic subsoil which is an elastoplastic medium following the Coulomb Mohr's model. Parameters of subsoil are presented in the Table 1.

The plastic moment of the intersection of concrete is M_c = 2128 kNm/m, other properties of the tank: EA = 9,84E+11 kN/m, EI = 1,61E+10 kNm^2/m.

Two options of the load were examined:

1) The load which is symmetrical.
2) The load which is symmetrical and concentrated forces coming from traffic A=B= 250 kN.

Elasto-plastic analysis was made with program PLAXIS [8].

The configuration of the subsoil's layers is presented in the Fig 6. The examination of the diagrams of inner forces and dislocations in stage 1 indicates a reasonable influence of the subsoil's heterogeneity. The influence of asymmetry of the load on the distribution of bending moments and the tank's settlement is also very important.

In this case one plastic moment in concrete was achieved after applying the load which value was A=B =250kN.

The calculations made on the substitute beam are necessary to assign the inner forces in the prefabricated units' connections. The load of the tank on the overburden coming from traffic increases additionally the inner forces. In the example above the acceptable settlement of the tank and the values of the bending moments are exceeded. It is easy to notice the range of the formation of plastic zones in soil. The solution indicates that for the safe foundation it is necessary to strengthen weaker layers of soil and define all zones where the traffic is not allowed. Analysis of the cross-section of the multi-chamber tank, which is founded on the erratic soil in stage 2, is presented in Fig. 9, Fig. 10. In the calculation three phases are needed. Each calculation is a plastic calculation. For each calculation phase the loading type Staged construction is selected, other settings are taken at their default values.

Table 1

soil layer	thickness of layer	Young's Modul E	Poison's ratio ν	Cohesion C	Friction angle	Weight γ
	[m]	[MPa]		[kPa]	[^{0}]	[kN/m^3]
sandy Clay	6	50,0	0,29	22	16,5	22
Clay	15	20,0	0,29	8	8	21
Sand	15	70,0	0,20	2	30	18

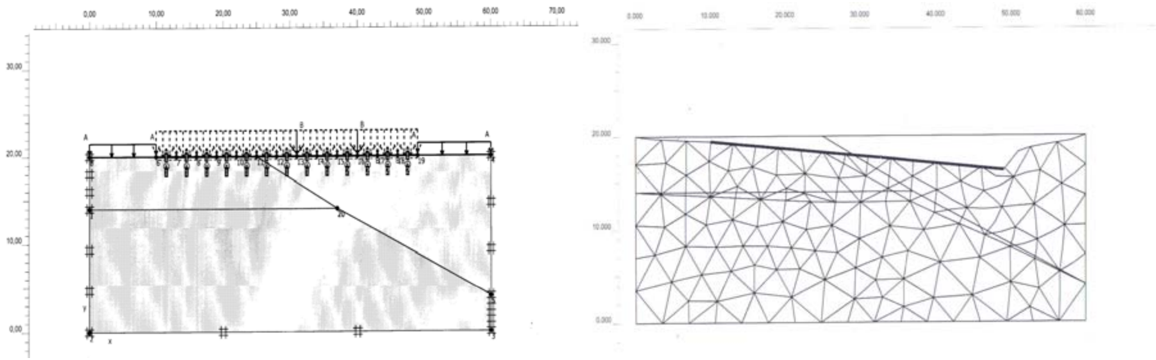


Fig. 6. The storage tank on the erratic subsoil at asymmetrical load and moments in a tank and deformed mash

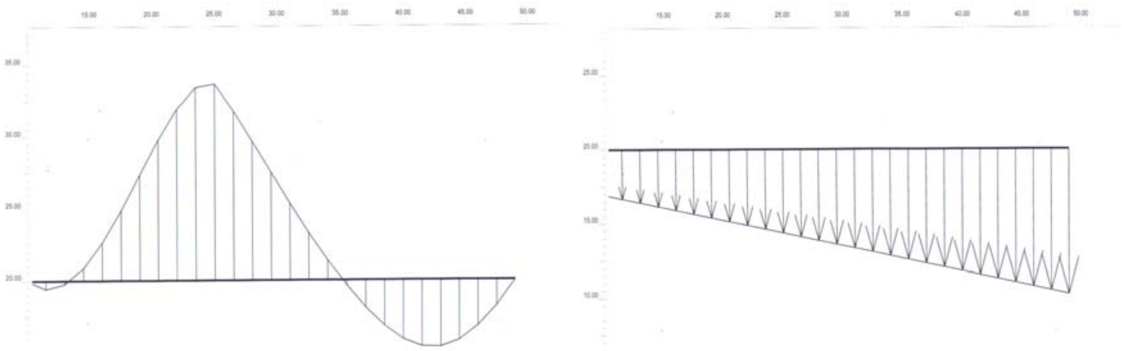


Fig. 7. Bending moments and the dispalcements in a tank at asymmetrical load

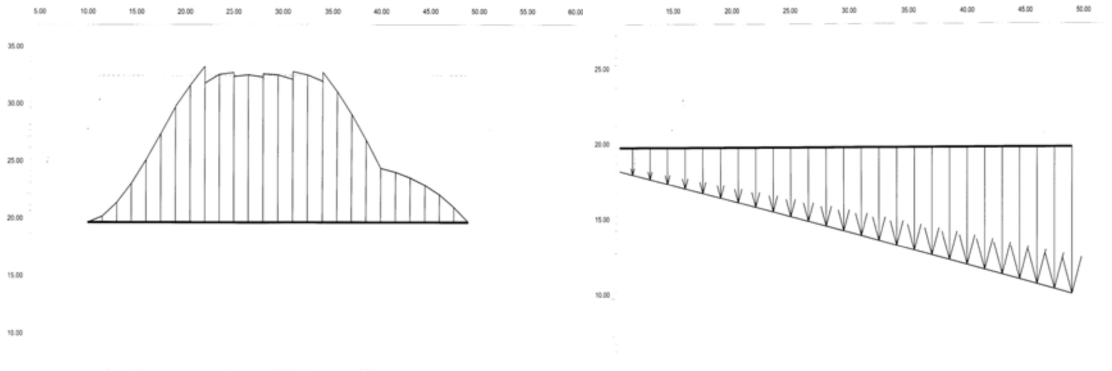


Fig. 8. Bending moments and the dispalcements in a tank at symmetrical load and concentrated forces

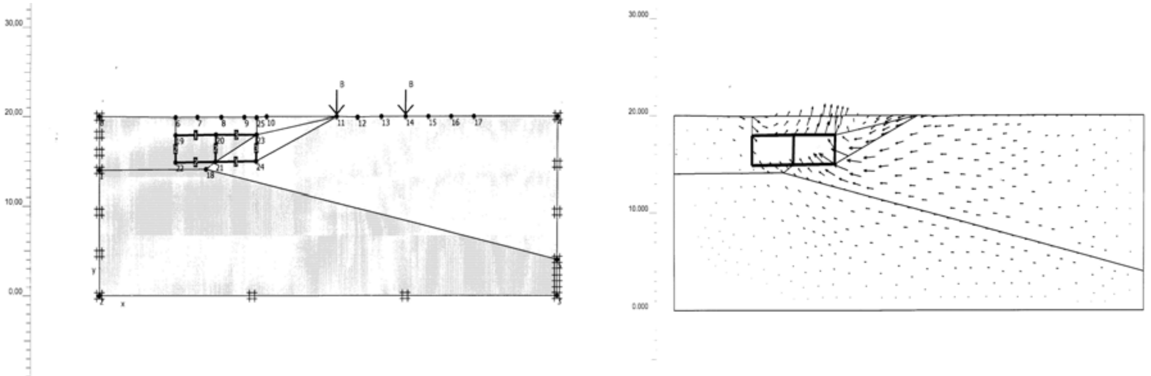


Fig. 9. The cross-section of the multi-chamber tank which is founded on the erratic soil and total displacements

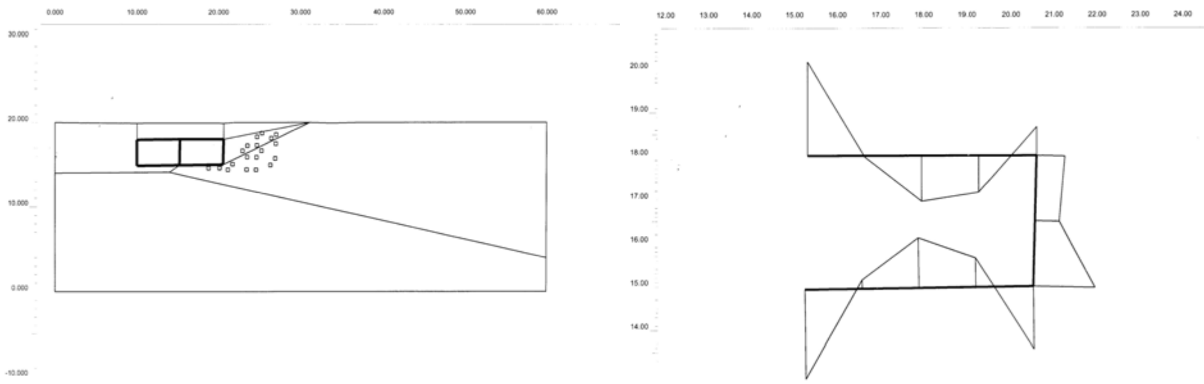


Fig. 10 Plastic points in a soil. Bending moments in the cross-section of the multi-chamber tank

In this case the real intersection of the tank is modeled. Heterogeneity of the subsoil is the reason of heterogeneous settlement of the tank and its effect is also achieving the plastic moment in the segment's node.

7. Conclusions

The prefabricated concrete storage tanks can be calculated as a beam on the elastic subsoil. Subsoil is normally modelled as a one-parameter Winkler's elastic medium, two-parameter elastic half space or more advanced models of subsoil are used. The best solution for the tank requires following steps: the analysis of geotechnical and technological conditions, considering the cost of the construction and the operational use of the tank. It is very important to take into account the actual rigidity of the beam, which can be constant on the whole length of the tank under one condition: it must be reduced in prefabricated units' connections and it must be enlarged on the tank's edge. The linear elastic subsoil is modelled as a one-parameter Winkler's elastic continuum, double-parameter elastic subsoil or some other advanced soil model.

While the subsoil is erratic it is necessary to estimate precisely the inner forces in the tank by using numerical methods. Subsoil is modelled in this case as an elastoplastic. The erratic subsoil can change the inner forces system. What is more in presented example, plastic moments in concrete are achieved and the acceptable settlement of the tank is exceeded.

8. References

[1] Brząkała W., *Fundamentowanie. Przewodnik do projektowania t. II,* Politechnika Wrocławska, Wrocław 1990. /inPolish/

[2] Elachachi S.M., Breysse D., Houy L., *Longitudidal variability of soil and structural response of sewer networks,* Computers and Geotechnics 31 (2004) 625-641, Elsevier.

[3] COSMOS/M Basic FEA System*,* Structural Research and Analysis Corporation, Santa Monica 1994

[4] Gorbunow-Posadow M.I., *Obliczenia konstrukcji na podłożu sprężystym*, Budownictwo Architektura, Warszawa 1956./in Polish/

[5] Górski K., Wyjadłowski M., *Calculation of precast concrete tank foundation on elastic subsoil,* Ovidius University Annals Series Civil Engineering, Volume 1, Number 7, Constanza 2005.

[6] Kobiak J., Stachurski W., *Konstrukcje żelbetowe, t. 2*, Arkady, Warszawa, 1989. /in Polish/

[7] Krasiński A., Tejchman A., *Obliczenia konstrukcji podziemnej komory rozładowczej w terminalu zbożowym w Porcie Północnym w Gdańsku,* XLVI Konferencja naukowa KILiW PAN i Komitetu Nauki PZITB, Krynica 2000 /in Polish/

[8] PLAXIS Version 8 Tutorial manual. Plaxis BV, Delft

[9] Wiłun Z., *Zarys geotechniki,* WKiŁ Warszawa 1993 /in Polish/

Polish Standards

[10] PN-83/B-03010, *Ściany oporowe. Obliczenia statyczne i projektowanie.* PKN, Warszawa 1983.

[11] PN-B-03264, *Konstrukcje betonowe i sprężone. Obliczenia statyczne i projektowanie.* PKN, Warszawa 2002.

Eutrophication reservoir monitoring by the software "Surface Modeling System"

Alina AGAFIȚEI [a] Marius AGAFIȚEI [a] Victor GABOR [a] Oana COMISU [a]
[a] *"Gh. Asachi" Technical University Iassy, Iassy, 700353, Romania*

Rezumat: Lucrarea prezintă o serie de rezultate obținute de autori în domeniul studierii procesului de eutrofizare a apei lacurilor de acumulare. Rezultatele experimentale obținute după opt ani de cercetări sunt prezentate în comparație cu cele analitice privind efectele aplicării programului "Surface Modeling System" în cazul concret al lacului de acumulare Izvoru Muntelui – Bicaz.

Abstract: This work presents some results obtained by the authors in the field of eutrophication process study of storage lake's water. The experimental results of eight years of researches are presented comparatively with the analytical ones concerning the effects of applying "Surface Modeling System" program to local conditions for Izvoru Muntelui – Bicaz Storage Lake.

Keywords: *eutrophication, modeling, nutrients, trophic degree, software.*

1. Introduction

The adverse effects of nutrient enrichment of surface waters, 'aquatic eutrophication', have been identified as a major environmental issue at national and international levels. A range of statutory and international commitments, including EC Directives, the OSPAR Convention and the UK Biodiversity Action Plan, requires action to be taken to address the threats to the quality, ecology and uses of our waters. However, while these initiatives are helpful in controlling eutrophication, each addresses certain parts of the problem, rather than the whole.

In our country there exist over 450 storage lakes with volumes over 1 000 000 m^3, on the whole a gross volume of about 13,5 milliards m^3. Many of these, especially big storage lakes created significant negative effects on environment, some even catastrophic damages and losses of human lives.

Characteristic for lakes, especially for the artificial ones, is the evolution process off water quality, with the tendency of their eutrophication, fact with special problems regarding water treatment technologies.

This phenomenon is caused by the over limits increasing of nutrients concentrations (nitrogen, phosphorus) from lake's waters, substances involved through agricultural fields watering, fields on which were applied fertilizers.

Eutrophication – normal phenomenon as time as its evolution is natural – is between first six major environment problems from the world lakes and reservoirs. Percentage of lakes and reservoirs with eutrophication problems is as following: Asia and Pacific – 54%, Europe – 53%, Africa – 28%, North America – 48% and South America – 41% (conform data of UNEP/ILEC, 2000).

Eutrophication means a natural adapting process of structures and functions of the ecosystem parts at new conditions, so new created inter-relations are part of (eco)system characteristics and can not be substituted by characteristics of a subordinated subsystem. Thus, only the analyze of some principal components of subsystem and integrating them in a complex image of the ecosystem, dominated by an integrally systemic interpretation, associated with a cybernetic vision could follow to a correct understanding and classifying of the eutrophication process (Agafiței Alina, 2000).

ISSN-12223-7221

2. Researches: Lake Characteristics

Researches were made on the "Izvoru Muntelui – Bicaz" storage lake from Siret hydrographic basin, with a total volume of 1230 millions m^3 and complex first usage. Since 1960, Izvoru Muntelui storage lake is located in the middle basin of Bistrița river (Oriental Charpations). It is the greatest artificial (anthropic) lake made on internal Romanian rivers. On the superior course of Bistrița river, "Bicaz" lake was made through building of the hydro-energetic barrage with the same name. From it is feed the hydro-electric central Bicaz-Stejaru, equipped with six generators.

In the following of ecological succession Bistrița river – Izvoru Muntelui – Bicaz lake, physic-chemical parameters were considered as basic criteria in analyzing habitat changes and then biotic ones (Agafiței Alina, 2002). Also, *algae cenozis* structure was considered.

Hydro-chemical researches we made in lake (1998 – 2005) considered also the principal aspects of the new habitat: morphometric characteristics (depth, length, width), water mass dynamic, level oscillations, atmospheric conditions influence, also lake biotic development.

• maxim oxygenating, about 11 mg/L, in March, between 0-30 m, and two months later over 40 m, in May; then a decreasing with minimum values in September - October; minimum values are 6-7 mg/L at the bottom and 7-8 mg/L on surface;

• pH annual dynamic has characteristic fluctuations, function of period and depth (0 - 10 m), on the whole lake, with frequent values of 7,4 and 8,3; in depth, oscillations between 7,2 and 7,4, values that indicates a thin alkaline reaction of lake's water;

• decreasing nitrates values in warm period with about 1 mg NO_3/L, especially in trofogen layer; maxim values of 2-3 mg/L, minimum values of 0,5 – 2,0 mg/L;

•average annual values of phosphorus concentrations decrease from 0,040 mg/L in 2004 to 0,015 mg/L in 2005; there are no differences between vertical and horizontal distribution of this parameter.

In actual sediments of Izvoru Muntelui – Bicaz storage lake, organic matter values are decreasing, generally, with variations between 8 and 30 mg O_2/L COD. Maxim values were in summer.

• organic nitrogen from the actual sediments of the lake is present in variable quantities, not always correlated with the organic matter quantities.

Rata between organic N and ammonia decreases, so the transforming grade of this element from the first into the second form is smaller in the superior part of this lake (Table 1).

Table 1. Organic matter, organic C and organic N in considered stations, on different depths

Interval *(cm)*	Station	Organic matter *(%)*	Organic C *(%)*	Organic N *(%)*
0 - 5	Baraj	3.58	2.08	259.71
5 - 10		3.39	1.97	399.53
10 - 15		5.71	3.31	403.10
15 - 20		5.09	2.95	304.37
Average		**4.44**	**2.58**	**341.67**
0 - 5	Secu	3.75	2.18	349.82
5 - 10		3.58	2.08	137.01
10 - 15		3.29	1.98	287.93
15 - 20		3.97	2.30	404.72
Average		**3.65**	**2.12**	**294.87**

0 - 5	Hângu	4.20	2,44	267.27
5 - 10		3.75	2,18	273.08
10 - 15		3.36	1.95	241.63
15 - 20		4.90	2.84	544.72
Average		**4.05**	**2.35**	**331.67**
0 - 5	Călugăreni	4.98	2.89	338.60
5 - 10		7.93	4.60	315.15
10 - 15		3.64	2.11	298.17
15 - 20		3.58	2.08	280.08
Average		**5.03**	**2.92**	**308**

3. Correlation between water quality parameters from lake

For estimate some correlation and logarithmic equations to describe relations between some important water quality parameters from Bicaz lake, we considered the following parameters, respectively correlation:

-dissolved oxygen, function of temperature;

-organic matter, function of dissolved oxygen;

-nitrogen, function of total phosphorus.

It was used the average values of the considered parameters, for the period of 1995 – 2005, at h = 10 m depth, in section 1-1 located between Rugineşti and Hângu stations.

With these values, it was obtained the following correlation and logarithmic equation (Fig. 1):

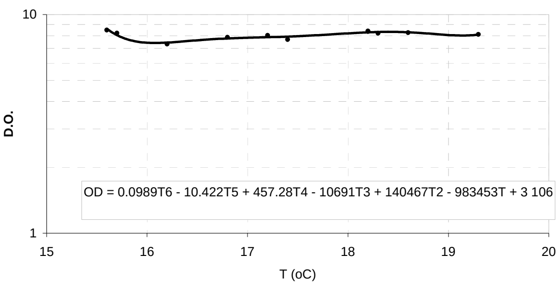


Fig.1. Correlation between D.O. (mg/L) and temperature values (^{0}C)

In the same way, we could establish correlation between every water parameters, in every lake section we have data, for any depth.

4. Monitoring of the eutrophication phenomenon

The reduction of nutrient inputs to water and control of eutrophication locally are shared responsibilities, involving a range of stakeholders. In taking forward this strategy, there are working Government departments, other environmental regulators, industry and interest groups. Tackling eutrophication will be a long-term commitment, linked to the general objective of contributing to sustainable development (Florescu, 1983; Macoveanu, 2003).

Reducing nutrient contributions from sewage treatment works and agricultural sources will be particularly important. In some instances it will be necessary to go beyond the sewage treatment measures set out in the Urban Waste Water Treatment Directive.

With regard to nutrient pollution from agriculture, we will promote a general reduction of nutrient inputs to water from the main sources, complemented by more concerted action in catchments where the impacts or risks justify this approach (Ryding & Rast, 1989).

On this purpose, we have been studied the application of the SMS ("Surface Modeling System") software – an environmental software used for hydrodynamic modeling of one-, two- and three-dimension, elaborated in "Environmental Modeling Research Laboratory" (EMRL), at Brigham Young

University, with help of the U.S. Army Corps, more exactly with Engineers Waterways Experiment Station (USACE-WES) and U.S. Federal Highway Administration (FHWA) – for local conditions from Bicaz lake.

“SMS” (“Surface Modeling System”) is a complex environmental programm used in uni-, bi- and tri-dimensions hydrodinamic modeling, elaborated by “Environmental Modeling Research Laboratory” (EMRL), at Brigham Young University, with help of U.S. Army Corps, more exactly with Engineers Waterways Experiment Station (USACE-WES) and U.S. Federal Highway Administration (FHWA).

SMS is a pre- and post-procesor conceived to modeling, analyze and design oh surface waters.

This programm also contained instruments for:

- management, edit and visualisation of hydraulic and geometric data;
- elaborate, edit and put data into mesh/grid format for numeric analyze; this include:
- “mesh” for finite elements (“unstructurated grids”), with instruments for:

-adequated to bottom conditions “grids”;

- linear and quadratic elements;
- all triangulare “mesh” and triangular – quadrilateral combinations;
- incorporate 1D elements in 2D and 3D “grids”;

- “grids” for finite diferences (“structurated grids”), with instruments for:

- rectilinear “grids” and known rotation.

- non-regulated triangulare ways (TINs).

Program’s interfaces are special created to facilitate using og numeric methods and include SMS’s modules.

SMS has six modules and one window is organized on the following sections (Fig. 2).

The proper approach for building some real, complex, concrete models is the one of conceptual modeling.

With these one, we create a conceptual model using GIS objects, including points, arcs and polygons.

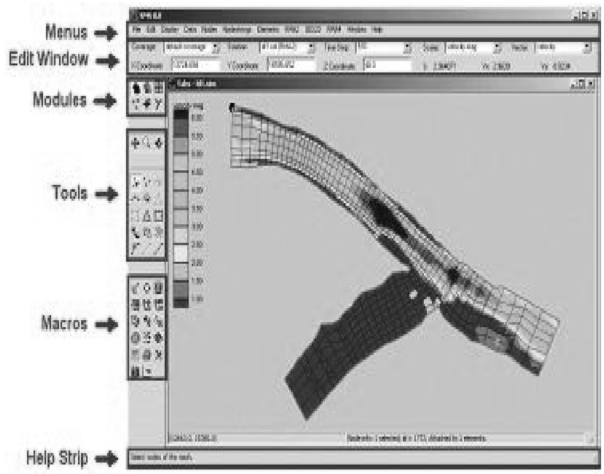


Fig. 2. Window of SMS program

Between two sections 1-1 and 2-2 established with lake’s data, conform existing norms, at h = 10 m, for each node (point), SMS knows automate plane coordinates (x,y) of nodes, in function of three points were we have the coordinates to create the program.

Nodes were made in points where we have data for the selected (wanted) field (lake) parameters. We made the same action for every wanted hydro-chemical parameter. For instance, in the particular case of phosphorus, the network looks like in Fig. 3.

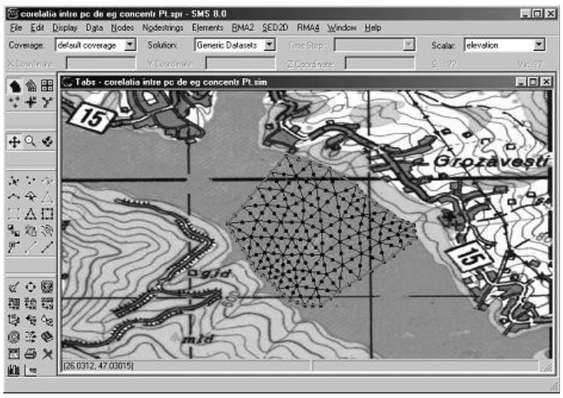


Fig. 3. Correlation between points of equal concentration for P total

We could make the same correlation, using SMS software, for every wanted hydro-chemical or biological parameter of the studied lake.

5. Conclusions

Algae cenozis structure modification, with an increase of green algae, especially of *Clorococcalae*, also of blue ones and of *Euglenae*, in our lake's ecosystem, due, in time, to a certain increase of biological productivity and at degradation of water quality, with not-wanted consequences on these, also on the environment (Eilers & Peters, 1988; Scheffer, 1998).

From the quantitative point of view, primary production appears, in the analyzed lake, as an expression of plankton activity, of the whole ecosystem's state, mode and organization degree (Leinster, 2000).

From in lake and laboratory researches maded in eight years (1998-2005), it was estimated that Izvoru Muntelui – Bicaz storage lake is integrated into oligotrophic lakes category.

In the same context are integrated graphic correlation regarding evolution of annual average values of hydro-chemical parameters from Bicaz lake, in period of 1995 – 2005, into a section (1-1) of this lake, between Rugineşti and Hângu stations, at h = 10 m water depth.

Researches we made in Izvoru Muntelui storage lake concluded to its integration into the **oligo-mezotrophic** level (trophic state).

Graphic correlation, with logarithmic equations to describe relations, permits to establish connections between any two water quality parameters for Izvoru Muntelui – Bicaz storage lake.

Using SMS software, we can establish correlation for points with the same concentration values for any required parameter important for the monitoring of the eutrophycation phenomenon in the considered storage lake.

Conclusions regarding principal hydro-chemical parameters of water quality which were analyzed are:

- air temperature, (annual average of 7 ÷ 7,5^{0}C), with warm winters (January's average of 4 ÷ -5^{0}C) and summers with moderate temperatures (July's average of 16,5 ÷ 17^{0}C); researches showed that, in October, warm contain per m^3 of water is maxim in this lake;
- water lake transparency regime, with maxims of 6 m in Baraj and Rugineşti sections, and of 3 m in "Coada lacului" section, in September and October, because of low precipitations from this period; then between 2 and 10 m in November, so we can say that Izvoru Muntelui – Bicaz storage lake is included in eutropiyc – oligotrophic (transit) category with moderate transparency.

Extinding researches for all lake's surface, eventualy considering other water depths (20m, 30 m etc.), we could conclude regarding lake's trophic degree, also regarding lake's water quality, in function of known quality parameters (date) for this.

We obtained conclusions regarding valoric distributions of equal concentration curves for each of the four indicators (determinants in eutrophication process study) with numeric values introduced in programm, so for each polygon we established increasinf, respectively, decreasing of their concentrations.

"SMS" verifies automate land date used, and alarming eventualy errors which could appear, contributing, in this way, at results accuracy.

Results could be applied for a considerable number of storage lakes. Thus, in researches made for a grant AT in 2000 – 2002 period, we extinded our work for six downstream lakes of hydrotechnical system "Bistrița downstream", also for some storage lakes from b.h. Siret.

This type og programms and models could contribute as an incontestable help to extinded researches for other storage lakes from Moldavia, in an organized way, by construction of a regional mycro-center for study this complex process.

6. References

[1]Agafiței, A., (2000-2002), *Contributions at studyof hill lakes eutrophycation from Moldavian Central Hill area. Preventing and controll methods.* Jassy (in Romanian), Grant AT no. 6177, theme B 31.

[2]Agafiței, Alina, Agafiței, M., (2002), *Contributions at study of lakes eutrophycation from Moldavian Central Hill*, Simpoz. U.S.A.M.V., Bucharest, F.I.F.I.M., 17-18 May, p. 313 – 318, ISBN 973-648-020-8.

[3]Cărăuş I.D., (1986), *Actual tendencies in preventing and hindering the lakes eutrophication*, Proceedings of the Research Center *Stejarul*, 5648, Pângăraţi, Neamţ.
[4]Cărăuş, I.D., (1986), *Water flowering – ecological consequences and limiting possibilities of the phenomenon*. Symposium Galaţi, sept.
[5]Eilers, P., Peeters, *J.,* (1988), *A model for the relationship between light intensity and the rate of photosynthesis in phytoplankton*. Ecological Modelling, no. 42, p. 199 – 205.
[6]Florescu, M.A., (1983), *Eutrophycation indices of some natural and artificial lakes in Romania*. Ph. Thesis, Bucharest (in Romanian).
[7]Leinster, P., (2000), *Eutrophication*. Environmental Protection Agency, USA, 32 p.
[8]Macoveanu, M., (2003), Methods and technics of evaluating the ecological impact. Ed. ECOZONE, Iaşi, 241 p. (in Romanian).
[9]Ryding, S.O., Rast, W., (1989), *The control of eutrophication of lakes and reservoirs*. Paris, vol. I, UNESCO.
[10]Scheffer, M., (1998), *Ecology of Shallow Lakes*. Kluwer Academic Publishers, Dordrecht, Boston, Chapman and Hall, London, 357 p.
***SMS (Surface Modeling System) program's Using Manual, USA, 2004.

Synthesis of the Composite Materials Characteristics

Gabriela DRAGHICI [a] Dorina Niculina ISOPESCU [b] Georgel PADURARU [c]
[a] *OIL Terminal, Constantza, Romania*
[b] *"Gheorghe Asachi" Technical University Iassy, Iassy, Romania*
[c] *University "Ovidius" Constantza, Constantza, România*

Rezumat: Articolul prezintă o primă sinteză a informațiilor existente în literatura de specialitate privind tipurile de materiale compozite, pe bază de polimeri, utilizabile în construcții. Se definesc sistemele compozite, componentele sistemelor şi funcțiunile acestora.

Abstract: The article presents a first synthesis on existent information in the specialty literature regarding the types of composite materials, based on polymers, used in constructions. There are defined the composite systems, the components of the system and their functions.

Keywords: *composite materials, composite systems, segment, reinforcement, fiber.*

1. The definition and classification of the composite materials

Creating new materials that covers a large area of exigency, imposed by the development in new parameters of constructions, is a permanent and stringent necessity. As a result of these conditions artificial composite materials appeared products of human intelligence, capable to respond to some multiple requirements of present and future development. In every engineering project choosing the most suitable execution materials is as important as the projecting process. That is why it is not surprising at all the fact that there are a huge number of materials, natural as well as artificial that are continuously improved, experimented and used.

The concept of composite material was utilized since ancient times but in the last four decades the specialists in different areas examine, conceive and use these materials scientifically. The performed researches have shown that the future belongs to the composite materials, because they combine rationally the favorable properties of the components and offer to the projector the possibility to supervise this process depending on the necessities. The artificial composites are a response to the impossibility of the traditional materials (wood, steel, stone) to surpass certain limits of properties, as well as a response of the new possibilities of analytic calculus and innovations in the architectural field.

The advantages of modern composite materials are:

- Improving the quality index of the used materials, their efficiency expressed as being the proportion between the braking resistance and density. This characteristic permits the reduction of the transversal section of the products and their weight.
- The modern composite materials can be projected so they can take over strain with approximate values at expanse as well as at compression, unto traditional materials which presents less durability at expanse than at compression.
- A new property and characteristic vis a vis traditional materials is represented by the possibility to create new materials or products with qualities and structures, especially conceived for a large variety of demands.
- Bringing in the economic circuit new sources of raw materials, some of them unexploited until now.
- Obtaining some important productivity incensement, during manufacturing (using ingenious technologies which allow producing some complex elements in very few technological steps, by associating different materials or the variation of the same material properties in its section) as well as during exploitation, with reduced maintenance expenses, with concordant qualities.

ISSN-12223-7221

1.1 The definition of the composite materials

Composite materials are multiphase systems artificially obtained, by associating at least two distinct chemical materials, with a clear separation interface between the components, and thus the resulted material is created with the propose of obtaining some properties that can not be obtained by any component individually [190].

The systems are defined as composite only if the component's properties differ substantially reported to those of the resulted materials. Defining some materials with the general term of composite is based on the significant change of physical-mechanical characteristics of these vis a vis the components.

Most composites were made to improve the physical-mechanical properties (resistance, hardness, stiffness) and the performances in severe stress conditions.

The composites include one or more discontinuous phases included in a continuous phase. The discontinuous phase, usually stiffer and much more resistant is called reinforcement, and the continuous phase is defined as a matrix or basic mass, fig.1.

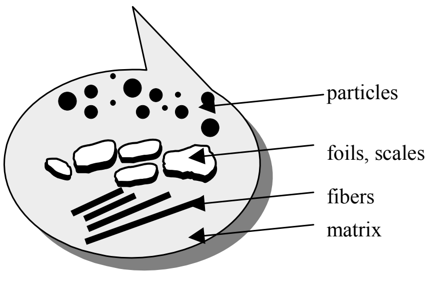


Fig.1. – The component phases of composite materials

The research and development programs lead to the permanent extension of the materials area and composite products of which efficient solutions can be selected efficient solutions for engineering structures too.

Reported to the alloys and super-alloys, the composites with metallic matrix have superior properties such as: high creep resistance, realizing a favorable report between the working temperature and the melting temperature, low sensibility at the thermo cycle, high mechanical resistance, high shock resistance, good structural stability in all domains.

Composite materials with ceramic matrix are now developed for special applications in parts with severe mechanical and thermo stress. They have increasing specific mechanical performances (reported to the mass unity) reported to the traditionally metallic materials.

The main advantages of these materials are: the superior mechanical behavior at high temperatures, where the best alloys even submitted to amelioration treatments lose their mechanical properties way before reaching the creep temperature; the crushing load resistance at normal temperature is considerably improved if there is abided by the condition that the maximum dimension of the micro-spaces is sufficiently reduced. The durability of the composite can be established with a very good approximation if the granulation of the powder and the composite density is well known.

The major disadvantages of the ceramic matrix composite derive from the high fragility of these multi-phased systems.

In the same group there are the cement matrix composites.

Nowadays it is accepted almost without reserves that the end of XX century and beginning of the XXI century define the so is called the synthetic materials era. Among the new materials, the macro-molecular complex based materials have a special place. For these materials, the dynamic production in the past 15-20 years shows the high development rhythm, the world production doubles itself every five years.

Referring to the products that have important mechanical resistance as well as stiffness characteristics, it is necessary to associate polymeric matrix with more resistant and stiffer materials, obtaining armed plastic masses. The reinforcement products can be made from a large variety of materials and with different shapes.

By the armature shape and nature, most of composites were created to improve mechanical properties (resistance, hardness, stiffness) and high temperature performances or in case of severe chemical aggressiveness conditions.

The reinforcement mechanism of a composite system depends on the armature geometry, that's why it is suitable a classification of composites based on the geometry of the representative armature unity.

In case of particle armed composites, the particles are reinforcements, having approximately the same size order in all directions [190]. Usually through particle reinforcement, breaking resistance improvement can't be obtained. The particles assume a part of the load, but armature contribution is significant in establishing the composite stiffness because the particles introduce some restrictions on the plastic distortion of the matrix between two reinforcement consecutive elements as a result of the stiffness difference between phases.

Composite with particles can be any system that combines different materials, choosing a certain association depends on the necessary characteristics: for example the lead particles in a steel and copper alloy matrix improve the workability, and those of molybdenum or chrome in a ductile mass improve the properties at high temperatures preserving the ductility at normal temperatures.

Powder additions (filer) are frequently used to modify the main mass properties: thermo or electrical conductivity, composite performances at high temperatures, wear and abrasive durability, workability, superficial toughness, contraction and last the material cost.

Fiber armed composites is the most important class regarding the using area and properties range. The fiber reinforcement can be directed so that they assure durability and/or stiffness when they are necessary, and to obtain the most efficient structural configuration due to the capacity of the composite material to adapt to different shapes.

The presence of some imperfections or some inerrant faults determines that the measured resistances of most materials to be lower than the theoretical ones. The fiber inorganic material products, due to the manufacturing manner that leads to elimination or at least cutting down the faults, have higher resistance reinforcement lengthwise. In the organic material case the resistance and stiffness incensement is due to the molecular structure orientation. For example, the higher resistance of glass fiber are explained through the surface fault elimination, while the black-lead and bromidic fibers improve the properties through the orientation improvement of atomic and molecular structure.

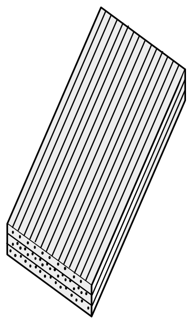
The fibers are not directly usable in engineering applications because they have very small transverse sections and are very sensitive to manipulation deteriorations. That is why it is necessary to include them in a base mass making the composite.

The transfer of efforts between components at discontinuous fiber composites is a complicated process and with substantial influences, compared with the systems based on continuous fibers.

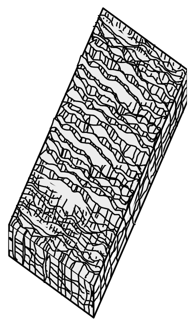
The fiber armed composites (fig. 2) are classified into two big groups based on the evaluation manner of theoretical and experimental properties:

a – *Monolayer composites* – are made up of some segments, with the same orientation and identical properties, fig. 1.2.a.1. The random orientation of unweave mats composites is approximately the same in every layer (fig. 2.a.3), that is why the resulted composite can be assimilated as being monolayer.

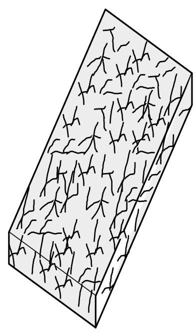
b – *Multilayer composites*- are formed from a sequence of elementary layers, pertained to the resistance and stiffness requirements of the final product, fig. 2.b.1.



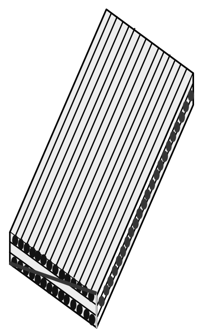
a1. Long fiber armed composites (continuous)



a2. Textile armed composites



a3. Short fiber armed composites (discontinuous)



b1. Hybrid composites (multilayer)

Fig.2. – Fiber armed composites

The elementary layer, called segment, has a typical thickness of 0.1 mm that is why it can't be used directly in the engineering applications, being necessary the assemblage of certain composites segments to achieve the final element. If the constitutive materials of each element are identical the resulted assembly is simply stratified. When the elements have different properties the assembly is called hybrid composite. It is possible the structure of hybrid composite in which the reinforcement is made with fibers with different properties. The long fibers composites are *called reinforced composites with continuous fibers* and the short fibers composites are called *reinforced composites with discontinuous fibers*.

It is supposed that where dealing with continuous fibers composites the reinforcement is the main carrying capacity component, the matrix having a protection and stress transfer role. The one directional composite are very strong in the fiber direction but weaker in the reinforcement normal direction.

There can be considered discontinuous fibers composites the systems in which the fiber length affects the composite properties through their termination effects. The control of short fiber orientation (discontinuous) is difficult, that is why in most cases it's accepted the supposition of random distribution and the quasi-isotropy in the elementary layer plan.

In most of cases, bedded products of fiber-armed composites in unidirectional reinforced layers forms differently oriented reported to the resistance and stiffness requirements. To increase even more the rigidity of the structure, the modular unities component of the structure can be fold or corrugated so that the structural qualities of cross-section through the correct distribution of the material can be used too.

Short fibred composites made through injection or die forging introduce where manufacturing a preferential orientation of the reinforcement thus the conduction of the material properties and the resulted products.

The bidirectional reinforcement can be made with fabrics so that the two primary directions resistance perpendicular with each other to be equal. From bidirectional armed composite (crosswise) can be obtained products whose mechanical characteristics values are about half of unidirectional armed composites.

Main advantages of the fiber composites derive from a favorable resistance/density and from controlled anisotropy report. The controlled anisotropy is conducting the values of some properties in different directions. For example at a unidirectional composite the report between the longitudinal resistance and the transversal resistance can be modified by changing the volumetric fraction of fiber. Other directional properties can be changed by modifying the fabrication parameters. These features determine the attraction of using the fiber armed composites in engineering applications.

Other advantages are the easiness of making it happen and the possibility to obtain some special structural efficiency shapes.

1.2. The role of the phases in establishing the fiber armed composites material properties

The segment is the elementary piece of the layered composite, made of a sample of matrixes and fibers, arranged in the way they are disposed in the product assembly, fig.3.

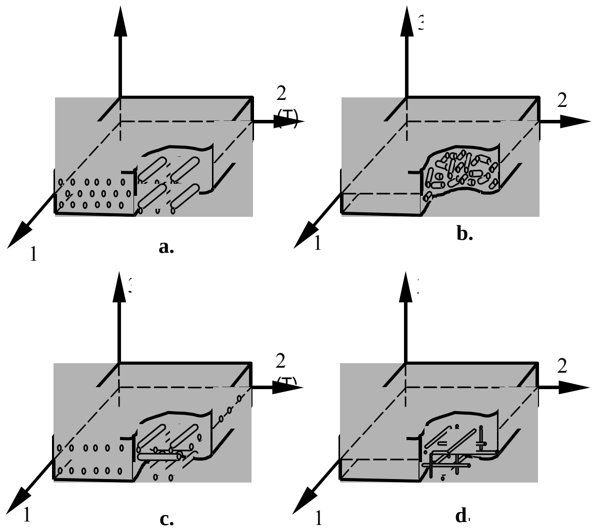


Fig.3. – The structure of the layered composite materials with different reinforcement systems [209]:

a. unidirectional continuous fibers;

b. discontinuous random fibers (short);

c. orthogonal net of fibers;

d. stratified with tri-directional reinforcement.

The two materials, as the main components of the segment are the matrix and the reinforcement. Their functions in the composite assembly are multiple, the most important are:

The matrix functions

- Covers the fibers so that they are protected during the forming phases as well as during their service period.
- Keeps the reinforcements at appropriate distances for transmitting the stress between phases through adhesion, friction or other pull together mechanisms.
- Prevents the buckling of the fibers, because without the maintenance medium the reinforcement is not capable to take over the compression stress.
- Constitutes the environment of transmitting the stress through the composite so that when breaking a fiber the others can reload through the interface contact.
- Assures the prime contribution to establish the resistance and stiffness on the normal fiber direction.
- Assures the tensions and strain concentrations redistribution avoiding the fast propagation of the composite crack.
- Establishes the last form of the product made from composite material.
- Establishes the transversal continuity between the elements of the stratified ensemble.
- Prevents the corrosive effects and reduces the abrasive effects on the fibers.
- Assures the thermo and chemical compatibility reported to the reinforcement material.

The matrix has a conclusive influence on some mechanical characteristics (especially on the transversal direction, in shearing and compression). The physical and chemical characteristics of the matrix such as intensification and melting temperatures, viscosity and the reactivity with the fibers, influence the choice of the fabrication process. The physical and chemical characteristics of the polymeric matrixes have a decisive influence on the composite materials characteristics. That is why the selected matrix for a composite system is chosen based on a factors sum.

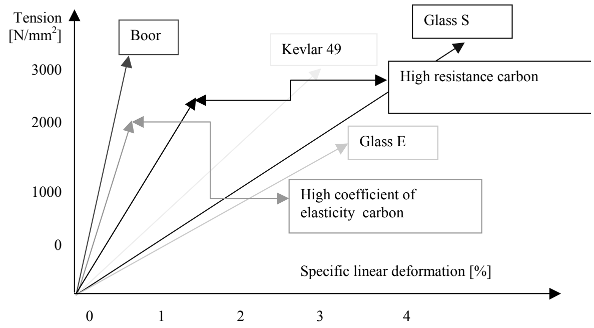


Fig.4. – Tension - specific deformation curves of the materials used to reinforce the composite

Reinforcement functions

- The reinforcement (due to the one-dimensional fiber nature) enables the growing of the composite stiffness and resistance mainly on the fiber direction, though some "lateral" contributions are not excluded.
- The growth of the composite resistance and stiffness is proportional with the volumetric fraction of fiber disposed in parallel with the stress direction, as long as the polymeric matrix assures the correct covering of the fibers and the efforts transfer between components.
- In case of some volumetric fiber fractions and geometrical arrangement of the reinforcement, the composite stretching resistance and stiffness increases by growing the relative stiffness of the reinforcement vis a vis the matrix.
- The fibers must have reduced variations of the individual resistances, homogenous geometrical characteristics and establishing the properties during the manipulation and making it happen operations.

The linear elastic behavior of the frequently used fibers in the composite production is fig.4. The chart allows the visualization of the specific tension-deformation curves, and facilitates understanding the difference between the mechanical characteristics of the used materials for reinforcing the composites with polymeric matrix.

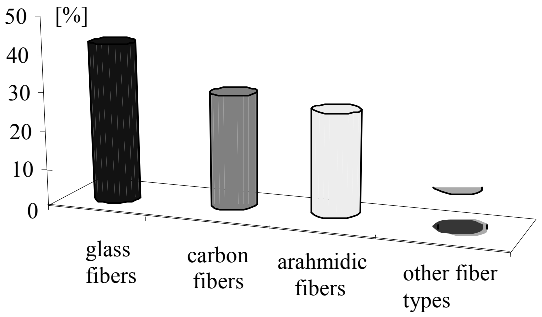


Fig.5. – World composites input distributed on fiber types [265]

Carbon fibers are more fragile than the glass and aramidic fibers. If the carbon fibers are used near metal or even over it, these fibers are bended to galvanic corrosion. That is why in these cases an interposing barrier is used like the one made of glass and resin fibers.

The stretching resistance of carbon fibers is equal with the one of glass fibers but the tension module of the carbon fibers it is three or four times bigger. The graphite fibers as well as the carbon fibers are resistant to the aggressive actions of the environment but must be treated for appropriate adherence with the polymeric matrixes.

The chart in fig.5 represents the importance that some fibers have in making fiber reinforced composites in the world, in 2000[265].

The analysis of a composite material can not be made without knowing the phenomena on the fiber-matrix interface. **The fiber-matrix interface** is a transition region with a graded evolution of the properties. The stress transfer at the interface is possible only if an intimate molecular contact occurs between the components in comparable distances with the ones in a regular material. The connection can take place on a chemical path or by intermolecular forces action. The fiber-matrix contact can be a third phase of the composite. The interface cession is usually critical because of the physical-mechanical characteristics of the multiphase system.

Polymeric composite materials are now used in the auto, spaceships, maritime industrial and architectural structures. In the construction industry the fiber reinforcements and polymeric matrixes used in the production of composite materials have earned a special place.

Due to the good conduct regarding the water and/or chemical agents' action, the fiber armed composites are applicable to silo constructions, draught chimneys, receivers, basins, channels, interior and exterior access scale, platforms, grids, and bridge floor. Concerning the tubes, if we make a price-quality analysis it's like this: replacing it with a new one or interior protection with composites, the parameters have comparative values except for the time which is in favor for the interior protection (fig.6). The composites are also successfully used for building or other types of constructions rehabilitation.

Fig.6. – The tubes rehabilitation using composite materials

2. Bibliography:

[1] Darby J. J. - *Role of bonded fiber-reinforced composites in strengthening of structures*, *in Strengthening of reinforced concrete structures*, Hollaway L C, Leeming M B, eds. Woodhead Publishing Limited, 1-10.

[2] Decher Emanuela - *Elemente şi structuri din materiale composite pentru acoperişurile construcţiilor inginereşti*, Teză de doctorat, I. P. Iaşi, (1998).

[3] Decher E., Ţăranu N., Isopescu D., Entuc I. - *Fiberglass reinforced plastics for mine structures.* In Proceedings of the International Conference INDIS 2000, Novisad, 109-114.

[4] Gurdal Z. et. co.– *Design and Optimization of Laminated Composite Materials*, John Wiley & Sons, Inc., New York, (1998).

[5] Halpin C. J. - *Primer and composites materials analysis*, Technomic Publishing Company Inc., Lancaster, (1992).

[6] Isopescu D., Secu Al., Ţăranu N., - *Caracteristici mecanice necesare proiectării produselor multifazice şi modele aferente (numerice şi experimentale),* Contract U.T. Iaşi-M.C.T. Bucuresti (1995), nr.267 B / A3.

[7] Drăghici Gabriela– *„Contribuţii la modernizarea construcţiilor industriale prin utilizarea materialelor compozite”,* Teză de doctorat, I. P. Iaşi (2004).

[8] Budescu M., Ciongradi I.P., Ţăranu N., Ciupală M.A., Lungu I. – *Reabilitarea construcţiilor*, Iaşi, Ed. Vesper – 2001.

Architecture of Composite Materials Used in Naval Industry

Alexandra NIȚĂ [a]
[a] *Maritime University Constantza, Constantza, Romania*

Rezumat: Lucrarea de faţă prezintă teoriile de bază ale materialelor compozite de tip lamină şi sandwich. Principalul obiectiv al acestei lucrări este acela de-a configura şi stabili arhitectura generală a materialelor compozite utilizate în industria navală. Studiul arhitecturii materialelor compozite ne va permite o înțelegere cât mai bună a comportării acestor materiale la solicitările compuse de întindere, încovoiere şi torsiune. De asemenea, clasica teorie a laminelor ne permite realizarea unei estimări a comportamentului elastic a straturilor ranforsate cu țesături sau cu alte materiale. Creşterea utilizării structurilor din materiale compozite de tip lamină sau sandwich a necesitat dezvoltarea aplicațiilor de modelare şi simulare a comportamenului lor mecanic.

Abstract: This paper develops the basics of the theory of laminate and sandwich plates and introduced the general assumptions of the various theories. The object of this paper is to set out the general architecture of composite materials used in naval industry. The study of the architecture of composite materials allows us to understand the phenomena of coupling between stretching, bending, and twisting. The classical theory of laminates also allows us to estimate the elastic behavior of layers reinforced with cloths or other materials. The growth of the use of composite materials in structures has required the development of the necessary tools for modeling their mechanical behavior and for the analysis of laminate or sandwich structures.

Keywords: *composite material structure, laminates used in naval industry.*

1. Introduction

The various manufacturing processes used for molding show the preponderance of designing composite material structures:

- surface: plates, shells
- lamination of successive layers.

This concept justifies the importance that will, be placed in the study composite materials in the form of plates or shells made of one single layer or of several distinct layers. Shells can be modeled as a set of plates. The object of this paper is to set out the general architecture of composite materials used in naval industry.

2. Arhitecture of Composite Materials

Laminates

Laminates are made of successive layers (sometimes called plies), figure 1, of reinforcements (strands, rovings, mats, cloths, etc.) impregnated with resins. The layers are successively designated going from one face to the other. Brackets (or parentheses) indicate the beginning and end of the code.

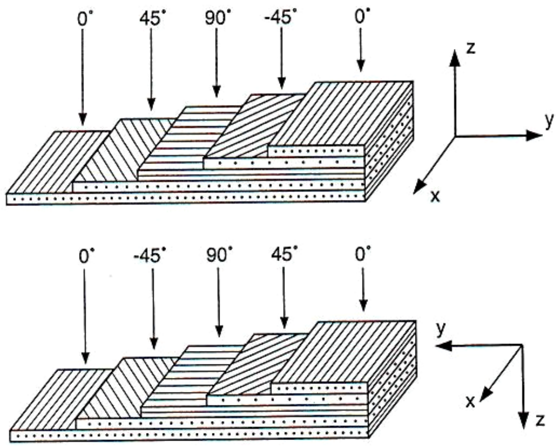


Fig.1.Constitution of laminates

ISSN-12223-7221

The designation depends upon the system of axes chosen. Laminates with unidirectional strands or cloth constitute a basic laminate to which, in theory, every other type of laminate can be reduced. These unidirectional layers are constituted of parallel fibers embedded in the matrix. Several unidirectional flayers can be stacked in a specified sequence of different fiber orientations to obtain a laminate that will fit the mechanical properties required.

In the general case the reinforcement in each layer will be of various kinds: strands, rovings, mats, cloths, glass fibers, carbon fibers, etc. Each layer must then be designated by the kind of fiber and the kind of reinforcement: strand, mat, cloth, with an indication of the proportion of fibers in the warp and weft directions.

The choice of the nature and sequence of layers will depend upon the use of the composite material, adapting it in the best way to the stress field applied:

• Unidirectional layers have good mechanical performance in the direction of the fibers.

• Mats have low resistance to tension and will have to be kept to compressed zones; for example, figure 2, unidirectional layers in the tension zone and mat in the compression zone of a beam subjected to bending.

• A cross-ply laminate will be sensitive to interlaminar delamination.

A lamination with at least three fiber directions will be necessary in order to have a pseudoisotropy in the plane of the laminate.

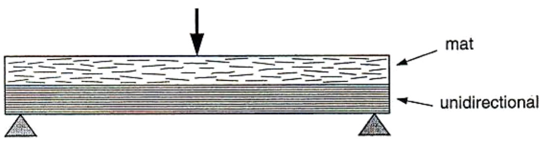


Fig.2.Loaded beam under bending

Sandwich Composites

The principle of sandwich construction consists in coating to a core (made of a light material or structure having good properties under compression) on both sides with two "sheets" or skins (having good properties under tension). The objective of such a process is to make a structure combining lightness and flexural stiffness.

Usually the choice of materials is made with the initial objective of having a minimal weight, next taking into account the conditions of use (thermal and corrosion conditions, price, etc.).

The materials most frequently used are:

- for *solid cores*:
  • balsa or cellular wood
  • plastic foam
  • resins filled with hollow glass microspheres, called syntactic foams
- for *hollow cores* essentially honeycombs and profiles of light metal alloys, paper (e.g., kraft, Nomex), glass fibers, etc. Mixed cores can be used.

The skins are most frequently laminates (glass, carbon, Kevlar) or light alloy sheets.

In order that sandwich constructions fully play their role it is necessary to ensure there is perfect bonding between the core and the skins so that the mechanical loadings can be transmitted between core and skins. The bonding is obtained by using resin systems compatible with the core material.

Other Architectures

Other architectures of composite materials can be schematically classified into:

• reinforced plastics
• volume composites.

Reinforced Plastics are made of resins or matrices in which reinforcements are introduced in the form of: short fibers, solid or hollow microspheres, powders: metallic; graphite. These reinforcements usually increase the modulus of elasticity by a factor of two to five. The mechanical behavior of these materials can be homogenized, and its study is then reduced to that of a usual isotropic material.

Volume composites were introduced for the specific needs of aeronautics. They are made from volume weavings. These materials are very expensive. In addition to the specific interests, they allow us to obtain very high mechanical properties with a behavior that is practically isotropic throughout their volume.

3. Consequences of the Study of the Mechanical Behavior of Composite Materials

The study of the manufacture of composite materials has shown the importance of laminates and sandwich materials. The architecture of these materials now indicate the guiding lines of the study of their mechanical behavior. This study will comprise two stages:

1. The study of the mechanical behavior of each layer, sometimes called the micromechanical or microscopic behavior of the composite. This study is quite often described by microanalysis of the composite material.

2. The study of the global behavior of a laminate constituted of several layers. The global behavior of a laminate is generally called the macroscopic behavior of the composite or the laminate behavior.

The analysis of the mechanical behavior of a composite material structure is shown schematically in figure 3.

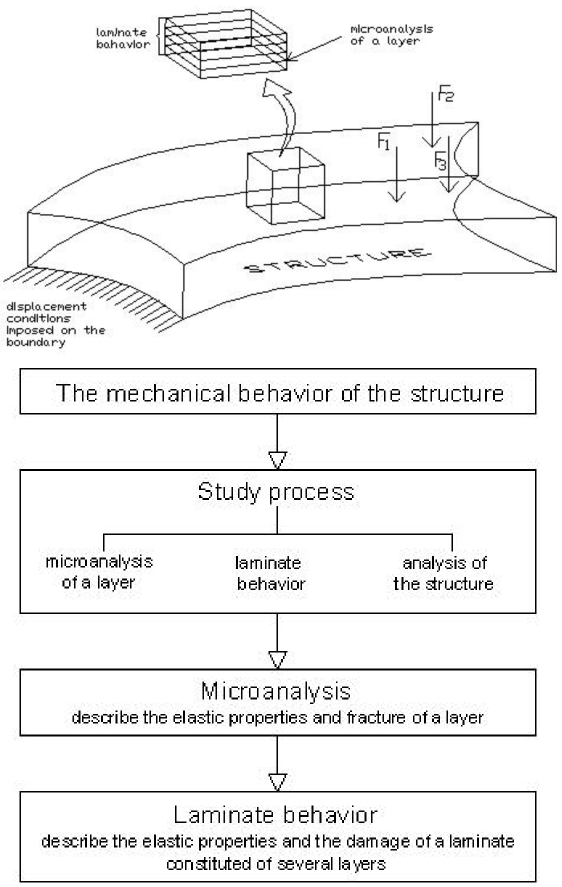


Fig.3.Schematic diagram of the analysis of the mechanical behavior of a composite material structure

When these studies have been carried out, the global mechanical behavior of a structure made of composite material will next be analyzed by adapting the classical tools of structural analysis to the macroscopic behavior of composite materials. The analysis of simple structures (beams and plates) can usually be achieved by an analytical method, although the study of complex structures requires the use of finite element methods.

4. Composite materials used in naval industry

The performance of future navy ships requires novel and innovative material and structural systems to meet ever-increasing design requirements. The application of composite materials for the primary structure of shipbuilding surface combatants offers the potential to meet these performance goals in the areas of increased payload fraction reduced life cycle costs and improved survivability.

Fiber/matrix composite laminates as well as cored, composite sandwich systems have consistently been shown, in both military as well as industrial applications, to result in weight savings of up to 70% compared to traditional metallic structures. These weight savings can be used to maintain the necessary stability criteria as a ship accommodates additional payload or weapons systems and increases in tonnage throughout its service life. The reduced weight may also be used to increase ship speed or mission range.

The layered configuration of laminated structures allows opportunities to embed and integrate specialized materials into the composite lay-up which provide improved electromagnetic performance.

A further challenge is that even as current composite applications become more accepted and standardized in design and manufacturing, the underlying technology and threats continue to move forward. Next generation composite ship structures will need to provide better performance to meet more severe blast, ballistic, and electromagnetic requirements than ever before. Achieving this in an affordable system will require improved resin systems, better core materials and a total integration of technologies into a true multi-layered, multi-functional structural system. Incorporation of these technologies and many others will forever change the appearance, design, and performance of the navy's future surface ships, as seen projected in Figure 4.

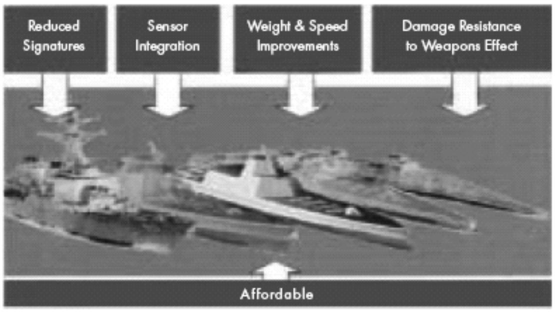


Fig.4.Evolution of the surface ships

5. Conclusions

Composite laminates are used throughout the marine industry for numerous applications including primary and secondary structure, superstructures, piping, shafts, foundations, ducts, and gratings. Most applications are in small commercial vessels and recreational craft, with composites use in offshore structures rapidly growing.

The technological advances in materials and new understanding of how composite materials behave under load have been crucial in the developments for the marine industry. It is essential to fully understand how these composites behave, because only that we can build stronger and lighter marine application.

6. Bibliography

E-mail: alexandranita@imc.ro
URL: http://www.imc.ro

[1] Hadăr A., *Structuri din compozite stratificate*, 2002, Ed.Academiei Române, Ed. Agir, Bucureşti
[2] Patrick Potter, *Surface Ships put composite to work*, Amptiac, vol.7, 2003
[3] ***A design and manufacturing guide, *Marine Composites*
[4] Soumitra BISWAS, Atul MITTAL, G. SRIKANTH, *Composites – The future building material.*

Stochastic Analysis of Breakwater's Stability

Isabella STAN [a] Dragos VINTILA [b]
[a] *Sport Department of Constantza, 900669, Romania*
[b] University *"Ovidius" Constantza, Constantza, 900524, România*

Rezumat: Lucrările de apărare exterioare sunt în general lucrări de protecție a zonelor de interes împotriva valurilor, în principal, dar şi împotriva curenților şi a sedimentelor pe care aceştia le transportă. Autorii O. Ditlevsen şi H.O. Madsen defineau in [3] că analiza structurală probabilistică este arta formulării matematice a modelului matematic prin care oricine poate întreba şi primi răspunsuri pentru întrebarea: "Care este probabilitatea ca structura să se comporte într-un anume fel atunci când una sau mai multe proprietăți ale materialelor componente sau dimensiunile ei geometrice sunt aleatoare sau incomplet cunoscute şi/sau când acțiunile la care este supusă au o natură aleatoare sau sunt incomplet cunoscute?".

Abstract: Harbor protection works are in general works for protection against waves streams and sediments. Autors O. Ditlevsen and H.O. Madsen define in [3] that probabilistic structural analysis is the art of formulating a mathematical model within which one can ask and get answer to the question: "What is the probability that a structure behaves in a specified way when given that one or more of its material properties or geometric dimensions and properties are of a random or incompletely known nature, and/or that the actions on the structure in some respects have random or incompletely known properties?"

Keywords: *stochastic, analysis, stability, random, waves.*

1. Probabilistic analysis methods

In civil engineering, there are many methods to estimate the safety of structures for a certain state limit. These include methods of Level 1, waves a coefficient is entered in equation in order to count the uncertainties from projection. The methods of Level 2 assures approximations of the safety, presupposing the equation state normal limit delivered and then transforming all the variables non-delivered in normal variables, delivered necorelate or doing a simplification a mathematics of the a form of the surface of failure, or both. Level 3 methods utilize the up-to-date distribution of random variables in order to calculate the equation of the state limit. Examples of methods:

A. *Direct integration*. Is a method of Level 3, and the probability of failure is evaluated through integration.

B. *Monte Carlo simulation*. Is a method of Level 3, and the function state safeseat limit, is approximated throught a large number of realizations through proportional realization waves state equation limit is larger than the state limit.

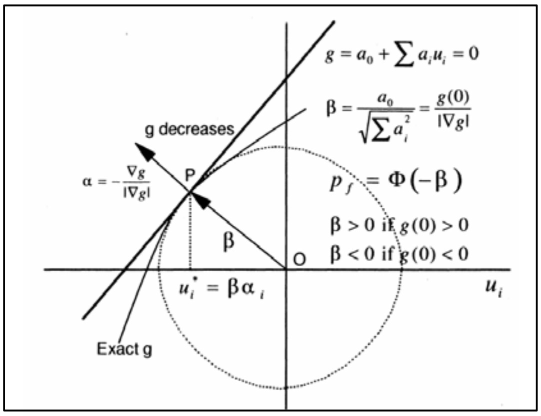
C. *Approximating in Taylor series*. Is a method of Level 2, and the function state limit is approximated through Taylor series. Safety is calculated as the the minimum distance between the surface of failure and zero.

D. *N-Points estimation*. Is a method of Level 2, where the function of probabilistic density of state limit is approximated through N points.

FORM (First Order Reliability Method), method in which the surface of failure is aproximated to hiperplan tangent and SORM (Second Order Reliability Method). FORM method is based on allignment of the function g in MPP in u space. The polynom is of 1st degree and is obtained through the Taylor's series of function g:

$$g_1(u) = a_0 + \sum_{i=1}^{n} a_i \left(u_i - u_i^*\right) \qquad (1)$$

ISSN-12223-7221



2. Stochastic analysis of breakwater's stability

The evaluation of structural safety is always connected with the structural answer defined as the mode of failure. All ways of failure are described by a formula, and the interaction among the different ways of failure must be known. For instance, it is considered a single mode of failure; Eg. "The weight of mantle blocks of concrete or stone that covers the part of a structure which is driven by the force of the waves" described by the formula:

$$W = \frac{\gamma_r H_S}{K_D (S_r - 1)^3 ctg\alpha} \quad (2),$$

W – Minimum weight of the blocks of concrete or stone;

γ_r - Unitary aerial weight of the block of concrete or stone

S_r - Specific weight of the block of concrete or stone below the water level.

α - Angle among slope and the horizontal plan

K_D – Coefficient of stability determined by the rate of mantle clench and the rate of produced damages, coefficient with the significance of distruction (movement of blocks).

H_S - The significant height of the wave.

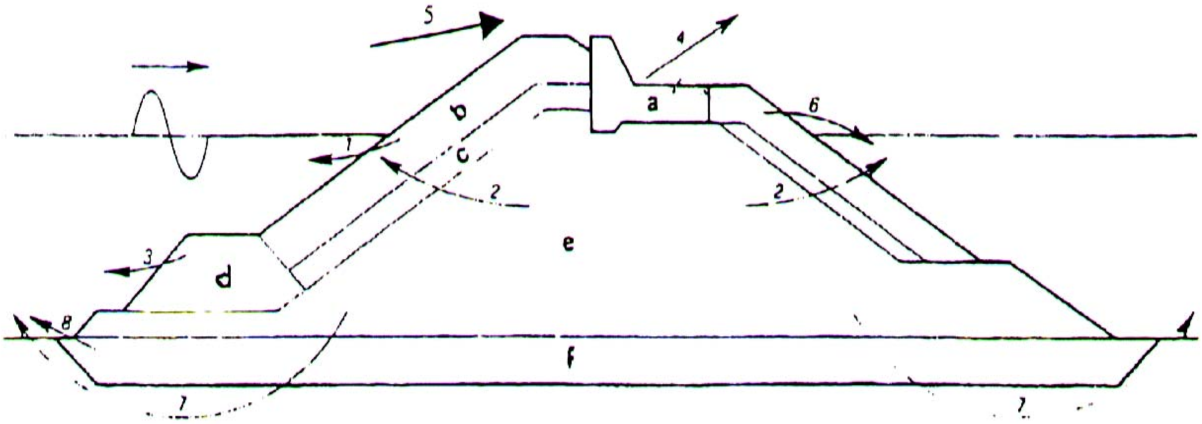


Fig 1 – Breakwater's types of failure

The above formula can be divided in varibles of shipments X_i^{inc} and varibles of resistance X_i^{rez}. If such a parameter grows and leads to a safer structure, it is a parameter of a resistance, but if such a parameter grows and leads to a unsafe structure then it is a parameter of shipments.

According to the above definition, a specific parameter can significate in a formula a measure of shipment, and in another formula a measure of resistance.

In the above equation H_s - is a parameter of shipment and all other variables are parameters of resistance. Starting from the formula (2), I expressed the equation in the form of the function of failure (or performance):

$$g = W \cdot K_D \left(S_r - 1\right)^3 \cdot ctg\alpha / \gamma_r - H_S$$

$$g \begin{cases} < 0 & FAILURE \\ = 0 & LIMIT\ STATE \\ > 0 & SAFETY \end{cases}$$

Is considered that all involved parameters are looked upon as aleatory variables, X_i, with the exception of K_D which significates failure – which is, a certain level of losses chosen by the structural designer.

With the help of the Nessus program [1,3] using the FORM method of calculation (Level 2), in which the function of performance was introduced, shown above, we obtain the following graphic reprezentations:

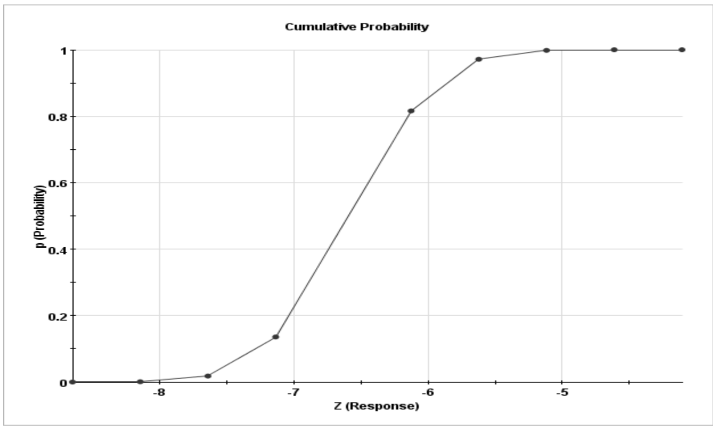


Fig 2 – Cumulative probability

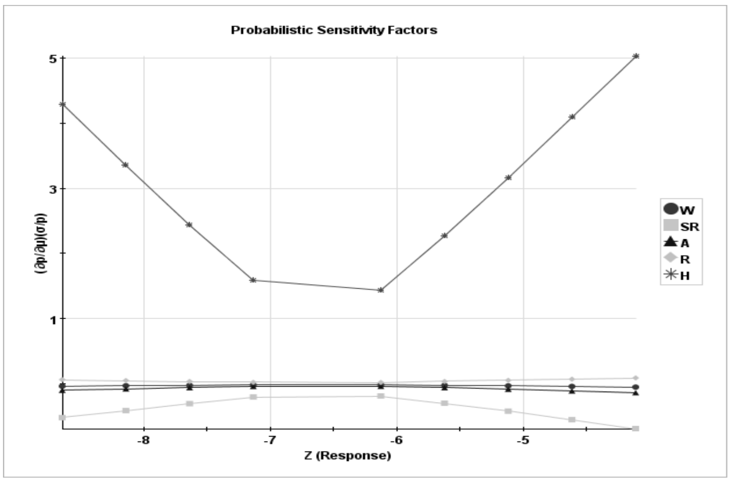
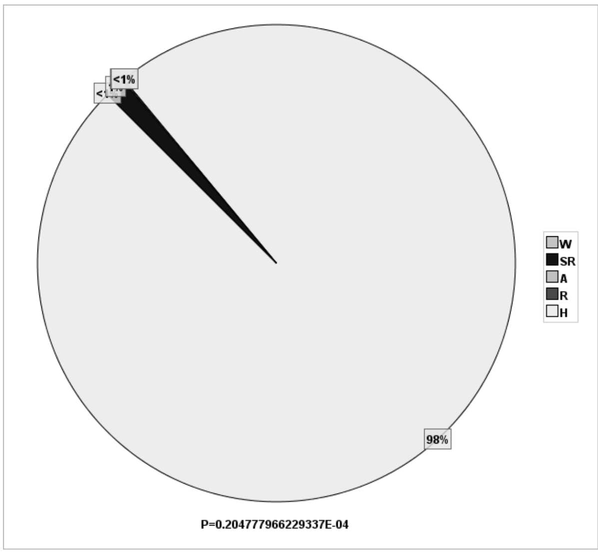
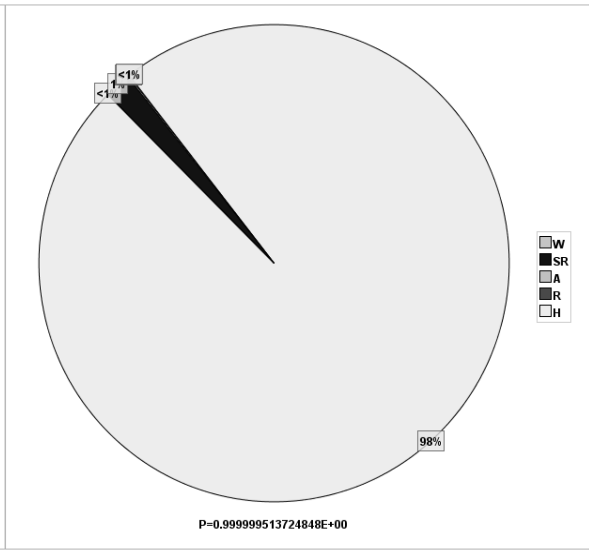


Fig 3 – Probabilistic sensitivity factors





3. Conclusions:

For different probabilies of failure obtained from analysis is obtained a graphical representation of probailistic factors of importance, in which we can observe that the importance of wave hights is constant for all Pf and the weight of concrete blocks or rock has a constant importance for all Pf.

If we impose g=0 (limit state), we can obtain Pf = **0.2421475931E-02.**

These results help us to identify the following advantages for these type of analysis:

- the probabilistic calculus, allows economic analysis to be made, accepting the general ideea of probability of faliure;
- actions on structures are better evaluated and a good way of cumulating hazards for different type of actions and risk evaluation and quantitative estimation of possible damages.

4. References

[1] *** NESSUS – „Theoretical Manual", Version 7.0, Southwest Research Insitute, October 2001.

[2] *** Tehnical standars for port and harbor facilities in Japan. The Overseas Coastal Area, Development Institute of Japan, Tokyo, 1991

[3] Dietlevsen O., Madsen H.O. *Structural reliability methods* , Coastal, maritime and structural engineering Department of mechanical engineering, Technical University of Denmark, July 2005