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Contents of Acta Technica Napocensis: Civil Engineering & Architecture Vol. 54 No.2 2011

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Seismic Protection of Guyed Masts via Added Damping

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Abstract

The intended contribution deals with assessing the seismic protection of steel guyed masts via supplemental damping. The assessment of seismic protection is carried out by computing several parameters associated to Performance Based Design of a guyed mast in the presence of six general levels of viscous damping. The mast is of 100.00 m high, with a constant triangular cross section of 1.20m side and anchored at two levels. An initial pretension of anchoring cables of 30% of their ultimate tension is considered. The structural elements of the mast have been designed according to current Romanian code provisions (via seismic response spectrum) and are the results of loading combination that includes the wind. The mast is located in a highly seismically area of a_g = 0.24g. An initial inherent viscous damping ratio of 5% is considered and other five general levels of damping (10%, 15%, 20%, 25% and 30%, respectively) are allowed for. The performed analyses are of time history type (recorded Vrancea 1977 N-S accelerogram) allowing for geometrical nonlinearity. The earthquake acts symmetrically versus vertical triangular cross section of the mast. Presented numerical results refer to the variation of lateral displacements (at the two anchoring levels and of the top of the mast) and the variation of tensions in cables with the amount of viscous damping.

Rezumat

Lucrarea prezintă rezultatele numerice ale eficientei protecţiei seismice pasive a pilonilor metalici ancoraţi prin amortizare vâscoasa suplimentara. Evaluarea eficientei amortizării se face prin compararea valorilor unor parametri asociaţi Proiectării Bazate pe Performante in prezenta a sase niveluri de amortizare vâscoasa suplimentara. Pilonul are o înălţime de 100,00 m, este ancorat la doua niveluri si are o secţiune transversala constanta cu latura de 1,20 m. Cablurile au o pretensionare iniţiala de 30% din valoarea rezistentei lor la rupere. Elementele structurale ale pilonului sunt rezultatul proiectării conforme cu prevederile in vigoare a structurilor amplasate in zone seismice. Secţiunile transversale ale elementelor componente au rezultat din gruparea de incarcari care include vântul. Pilonul este amplasat in zona seismica având a_g = 0,24g. Se considera o amortizare de tip vâscos iniţiala naturala de 5% si alte cinci niveluri de amortizare (10%, 15%, 20%, 25% si, respectiv 30%). Analizele sunt de tipul dinamice neliniare (accelerograma înregistrata Vrancea 1977 N-S). Cutremurul acţionează simetric fata de secţiunea triunghiulara a pilonului. Rezultatele prezentate se refera la deplasările laterale la nivelele de ancorare si la capătul superior si la variaţia tensiunilor in cabluri cu nivelul de amortizare.

Keywords: guyed metallic masts, supplemental viscous fluid damping, passive seismic protection

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1. Introduction. Analyzed structure

The present contribution refers to the effectiveness of passive seismic protection via supplemental viscous damping of metallic guyed masts. A metallic guyed mast of 100.00 m high anchored at two levels and having a constant triangular cross section (1.20 m side) is considered. The mast is located in a highly seismically area of PGA = 0.24g. The mast, Fig. 1, has been designed according to current Romanian and European provisions [1,2,3,4] in the elastic domain. No dissipative zones have been provided for. Its structural components, Fig. 2 and Fig. 3 are the results of the loading combination that includes the wind, ice on cables, snow (on possible equipments) and pretension. The stress state of main structural elements is in the range of 80% ÷ 85% of their axial stress bearing capacity. The geometry of triangular cross section, Fig. 2, is kept constant along the entire height of the mast while as well as the tubular cross sections of its three vertical legs, Fig. 3 (Φ159x12.5) and lattice (tubular sections Φ70x5 – diagonals) elements. An initial pretension (320.00kN) in the cables of 33% of their ultimate tension (961.00kN) is considered. Also, an initial inherent viscous damping ratio of 5% is taken into account [2,5,6]. The seismic action is introduced via Vrancea 1977 N–S recorded accelerogram symmetrically with respect the triangular cross section of the mast. The carried out analyses are of time history type allowing for geometrical nonlinearity. Computed results refer to the lateral displacements at the two anchoring levels and at the top of the mast. Also, the variation of tensions in the cables versus the supplemental damping levels is computed and presented. The analyses are performed considering five supplemental viscous damping levels of 10%, 15%, 20%, 25% and 30%, respectively. The contribution focuses on the effectiveness of supplemental fluid viscous damping from the point of view of the values of static (stresses in structural elements, tensions in cables), kinematical (displacements, accelerations) and synthetic (story drifts, ductility coefficients) parameters associated to Performance Based Design. Also, taking into account that the elements cross sections are – usually – the results of loading combination that includes wind rather than earthquake, the present contribution focuses on the seismic behaviour when the masts are located in highly seismically areas.

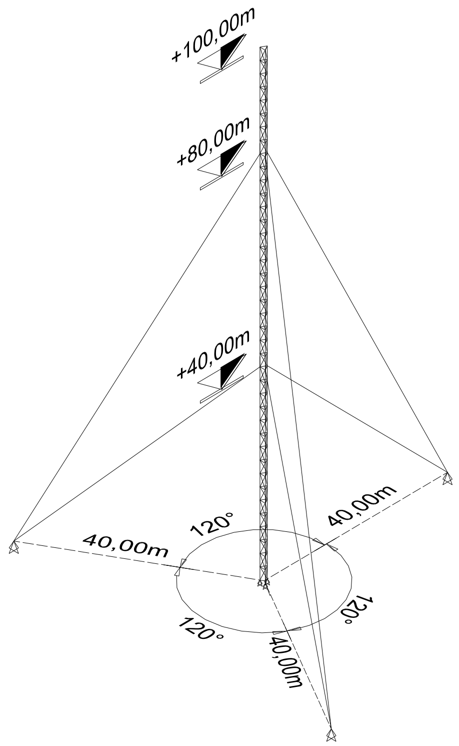

Figure 1. Guyed mast.

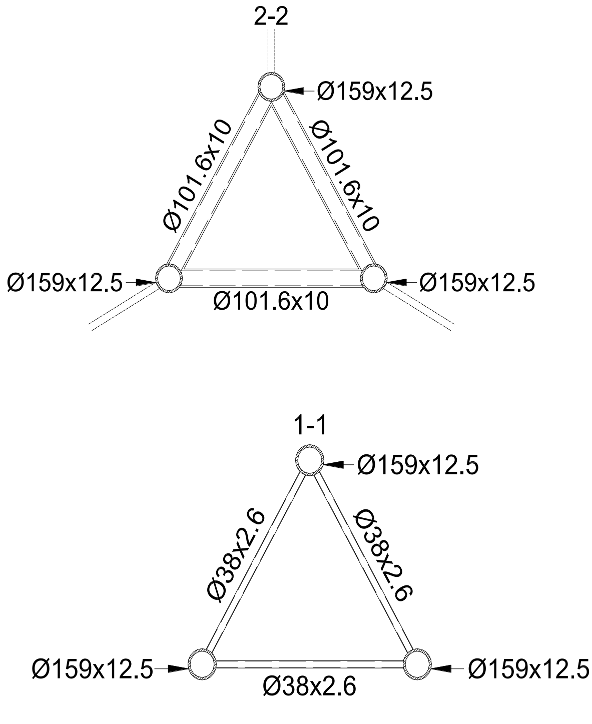

Figure 2. Cross sections.

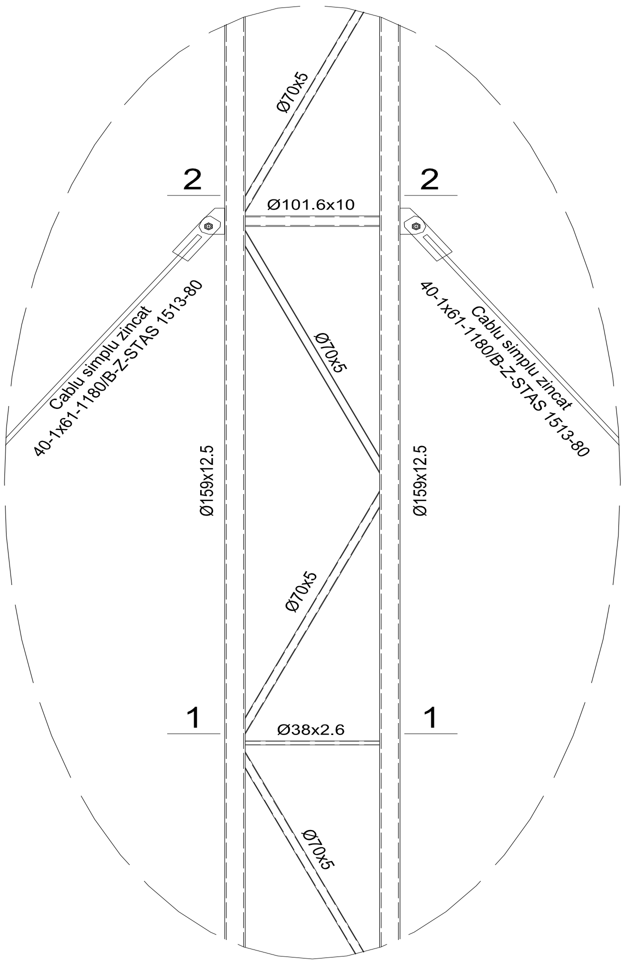

Figure 3. Detailed lateral view

The cables have been selected according to Romanian standard SR EN 12385 [7]. They are galvanized cables of wrap type of Φ40 mm diameter and are made up of 61 wires each.

Each wire is 1180.00N/mm^2 ultimate tension. The ultimate tension of the cables is 961.00 kN.

The initial elasticity modulus of cables is $E = 1.5\cdot10^8$ kN/m^2.

The lengths of the cables are:

l = 56.56 m for the lower cables and l = 89.44 m for the upper cables. The initial sags (before loading, but after applying the pretensioning) measured normal to the chord lines of cables are:

f_1 = 8.86 cm for the lower cables and f_2 = 22.06 cm for the upper cables. These initial sags lead to following f/l ratios:

$f_1/l = 1.56\cdot10^{-3}$ for the lower cables and $f_2/l = 2.46\cdot10^{-3}$ for the upper cables, respectively.

Cross sections 1 – 1 and 2 – 2 through the mast figured in Fig. 3 are presented in Fig. 2.

2. Applied loadings and performed analyses

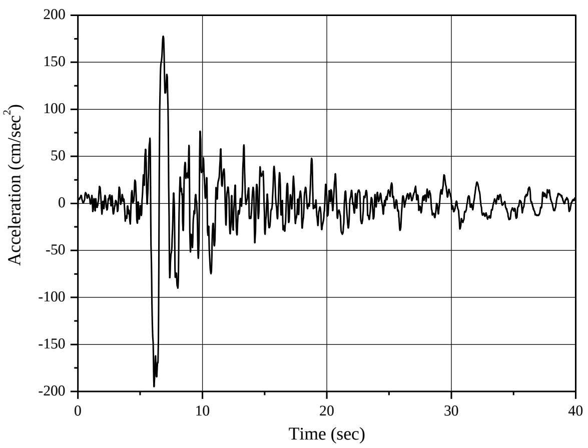

Figure 4. Vrancea 1977 N-S accelerogram

As it has been mentioned, the cross sections of mast elements (vertical legs and lattice members) are the design results of loading combination including the wind (35.00 m/sec.), ice on cables, snow and cable prestressing of 33% of cable tension capacity. The performed analyses are of time history type via Vrancea 1977 N – S recorded accelerogram presented in Fig. 4. The time history analysis has been performed in six cases of general damping levels, as it has been mention above. In the present contribution, no technological details of added damping are given. The analyses are carried out in the elastic domain of structural behaviour.

3. Numerical results

The numerical results computed refer to the natural modes of vibration (eigen forms and eigen periods), to the variation in time of lateral displacements at top tower ("joint 3") level and the two anchorage levels ("joint 2" and "joint 1") and to the variation of the three lateral displacements in terms of general damping levels. For the sake of brevity, only the displacements of "joint 3" and of "joint 2" are presented. The location of the "joints" is presented in Fig. 14.

Displacements of joint 3 (top level of tower) are shown in figures below.

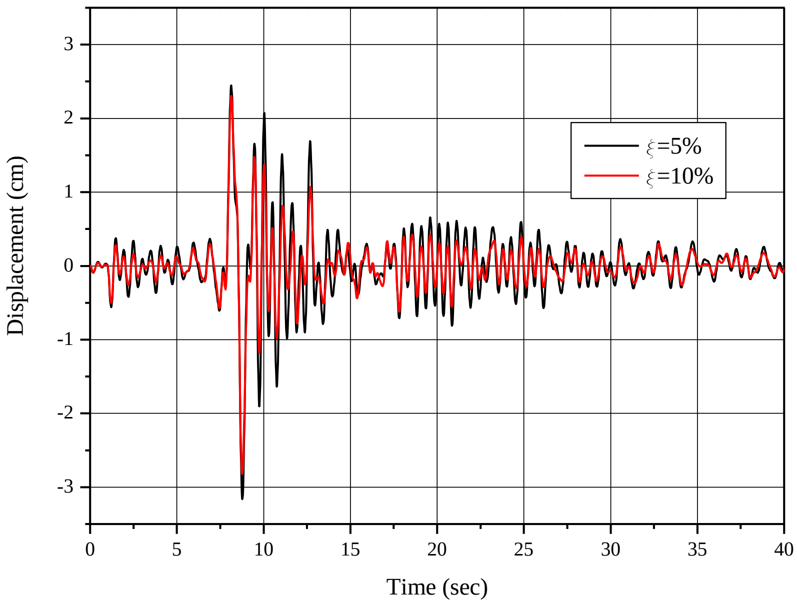

Figure 5. Lateral displacement of joint 3; ζ = 10%

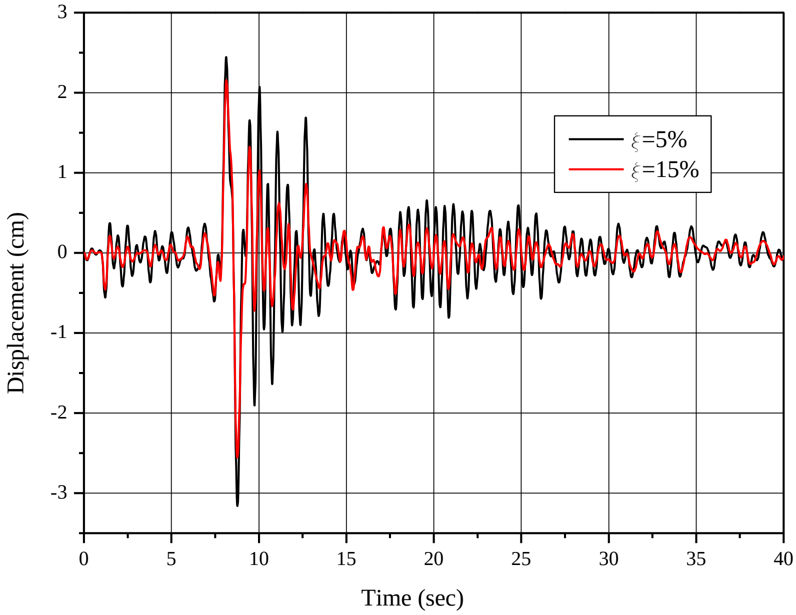

Figure 6. Lateral displacement of joint 3; ζ = 15%

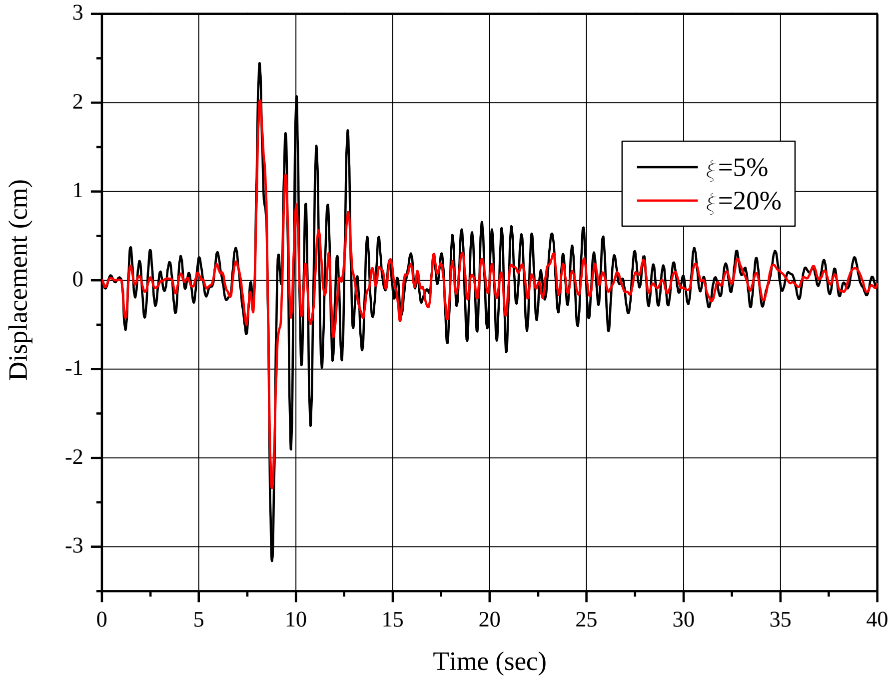

Figure 7. Lateral displacement of joint 3; ζ = 20%

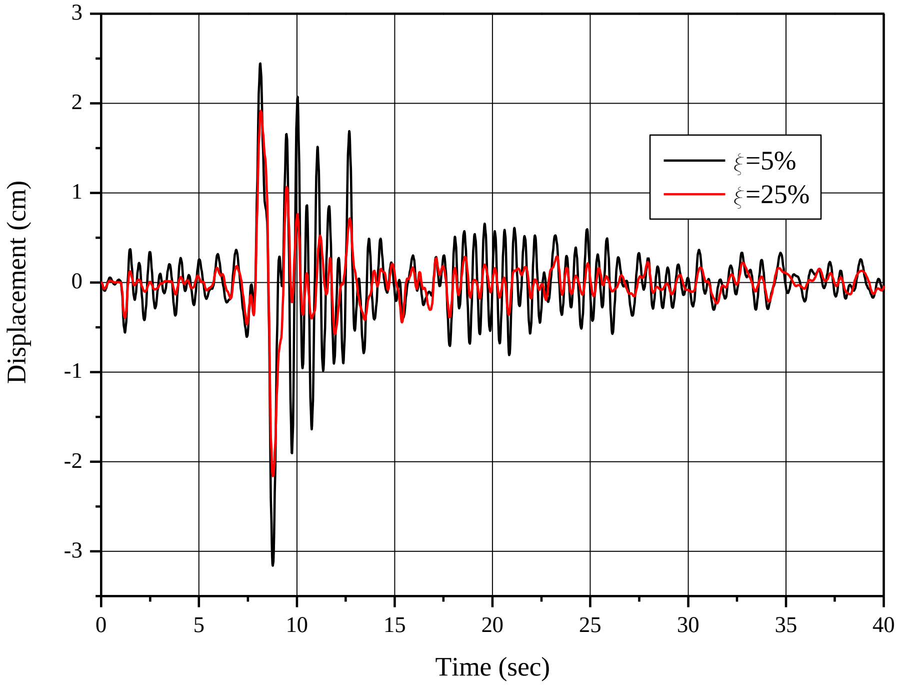

Figure 8. Lateral displacement of joint 3; ζ = 25%

To underline the effect of supplemental damping on seismic behavior of analyzed structures, the variation of lateral displacements is plotted separately for every damping level versus the variation of displacements in the presence of the inherent (natural) damping level of 5%.

The reduction in the peak values of lateral displacements, as well as the time interval the reduction is achieved exhibit the effectiveness of supplemental damping in mitigating seismically induced effects on guyed steel masts.

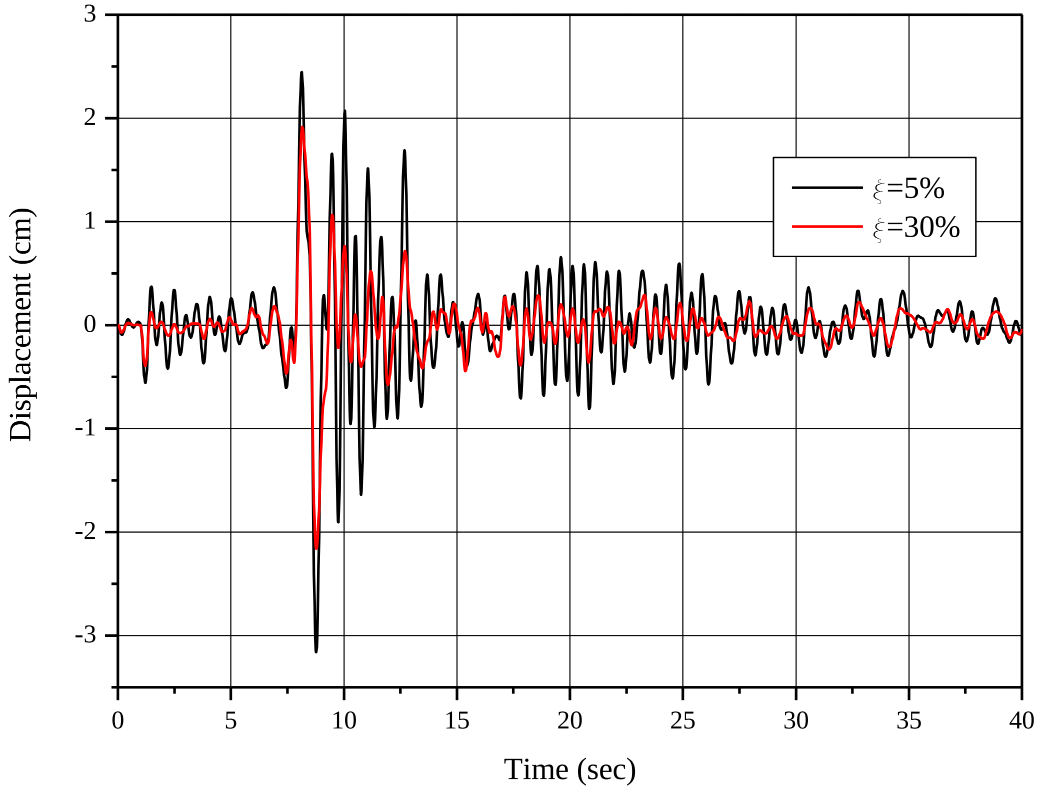

Figure 9. Lateral displacement of joint 3; ζ = 30%

Displacements of joint 2 (+ 80.00 level of anchorage) are shown in figures below.

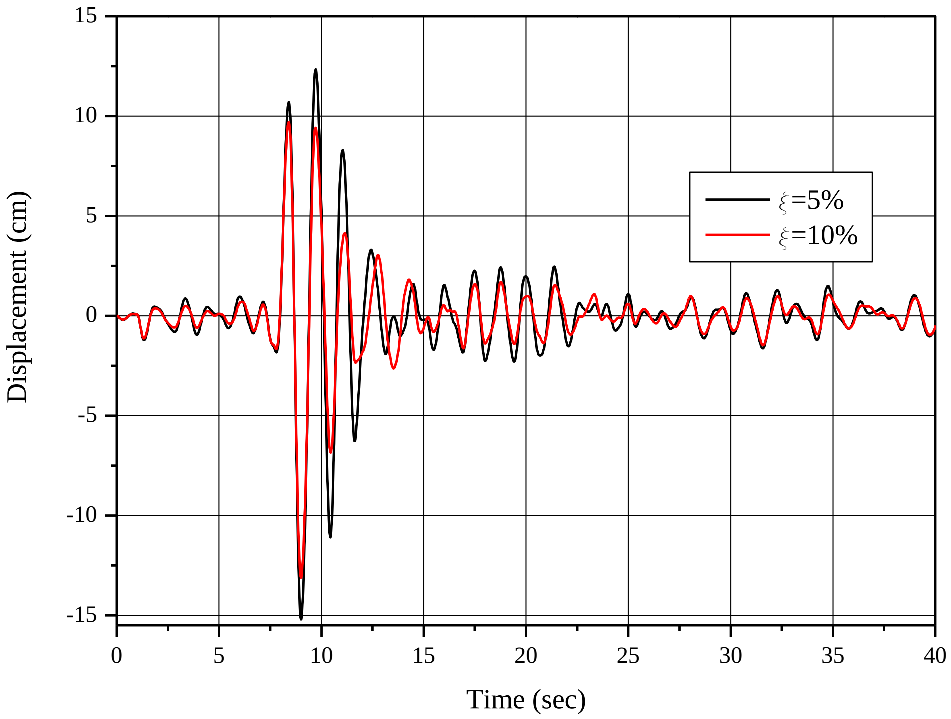

Figure 10. Lateral displacement of joint 2; ζ = 10%

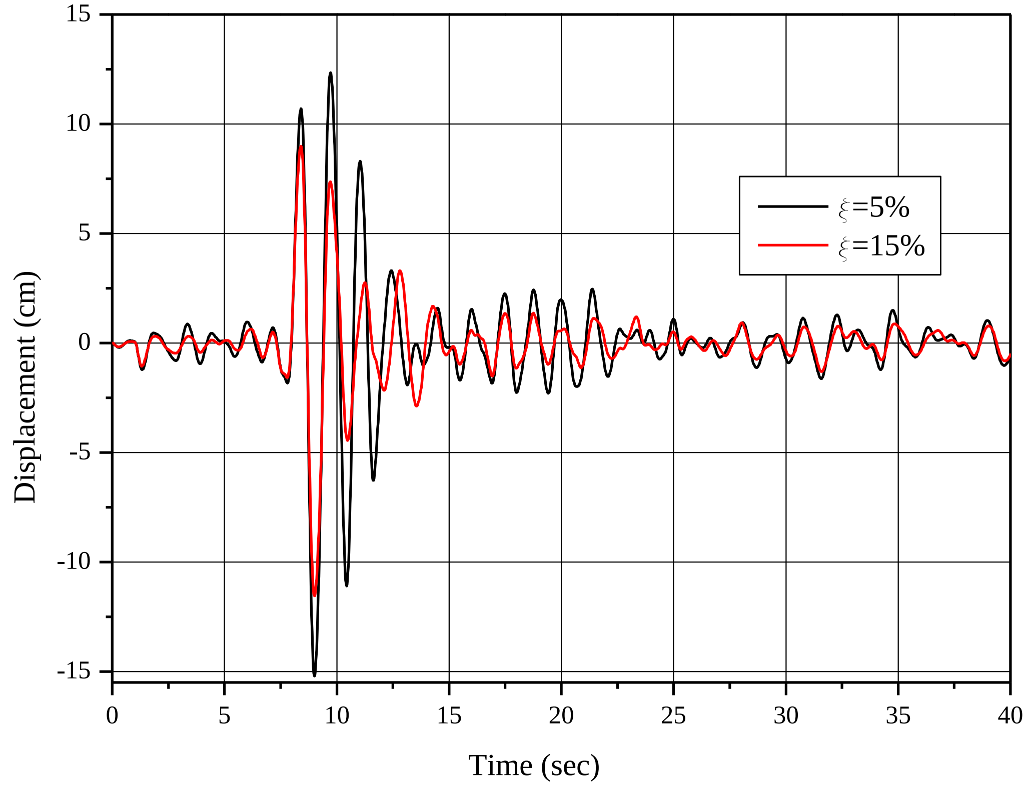

Figure 11. Lateral displacement of joint 2; ζ = 15%

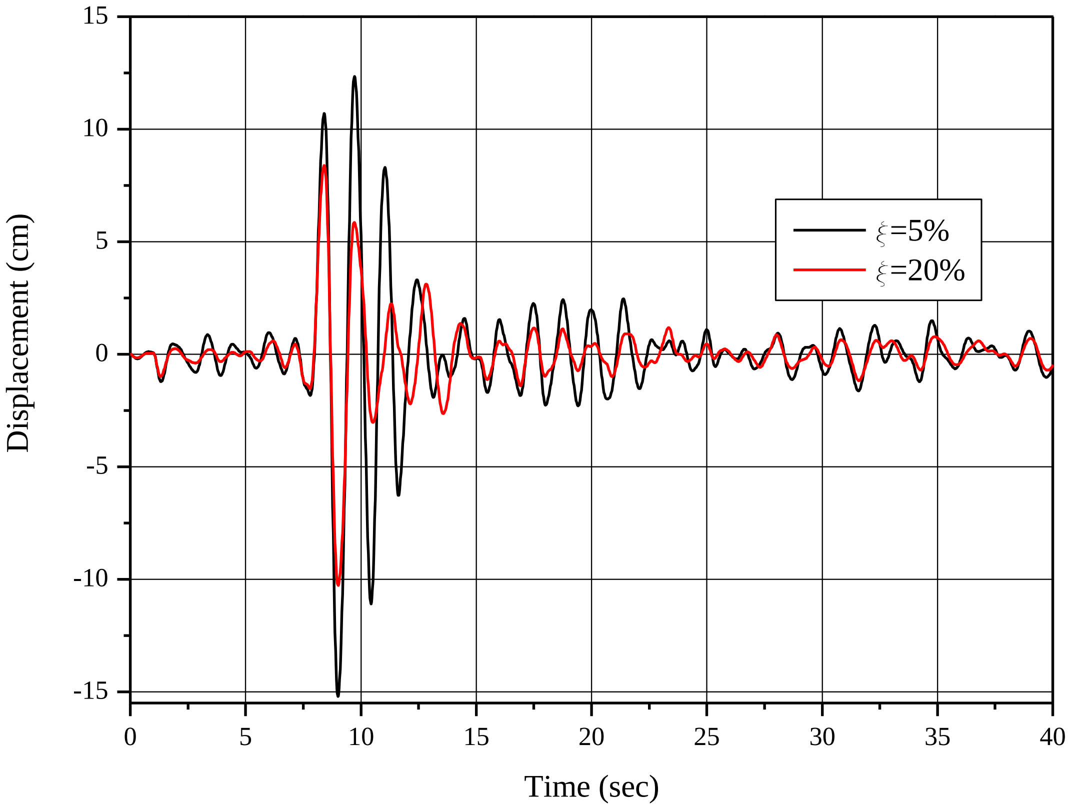

Figure 12. Lateral displacement of joint 2; ζ = 20%

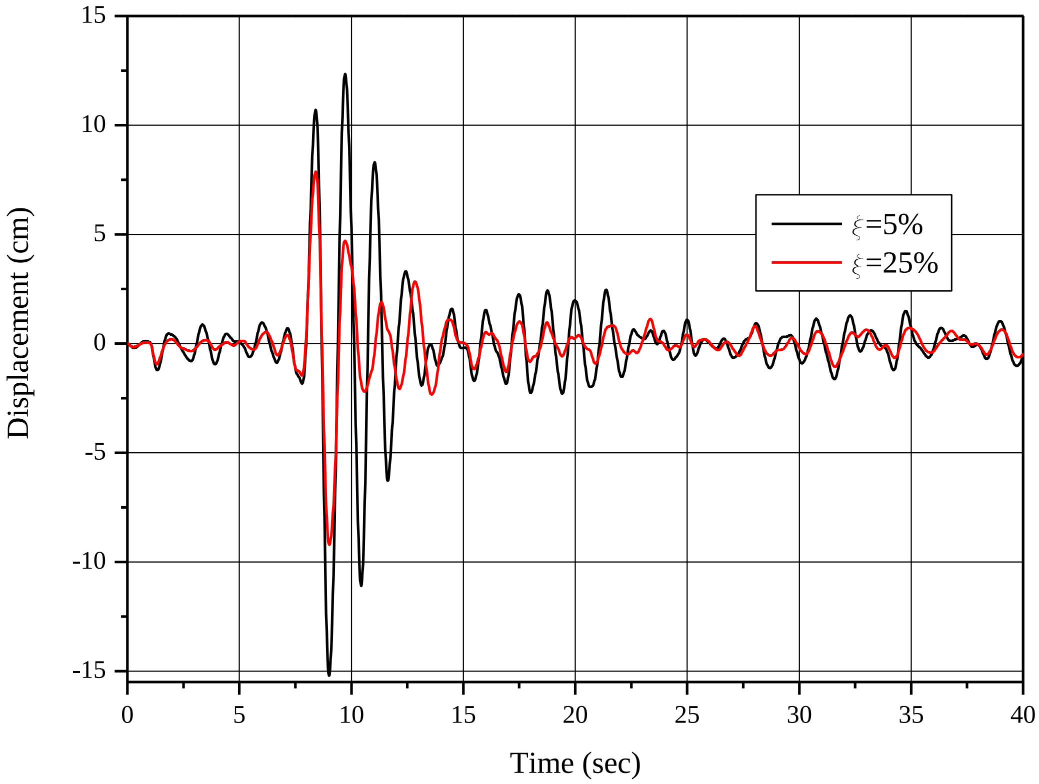

Figure 13. Lateral displacement of joint 2; ζ = 25%

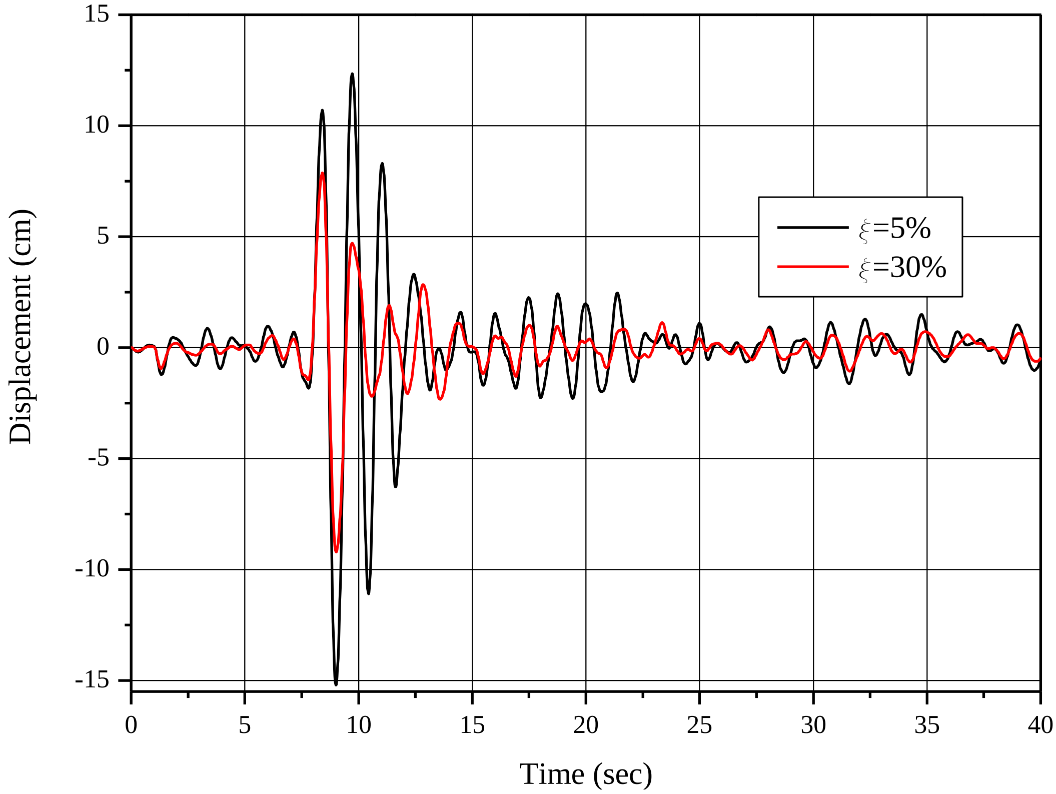

Figure 14. Lateral displacement of joint 2; ζ = 30%

A synthesis of above presented results is shown in Fig. 15 where the variation of displacements refers to all three anchorage levels ("joints").

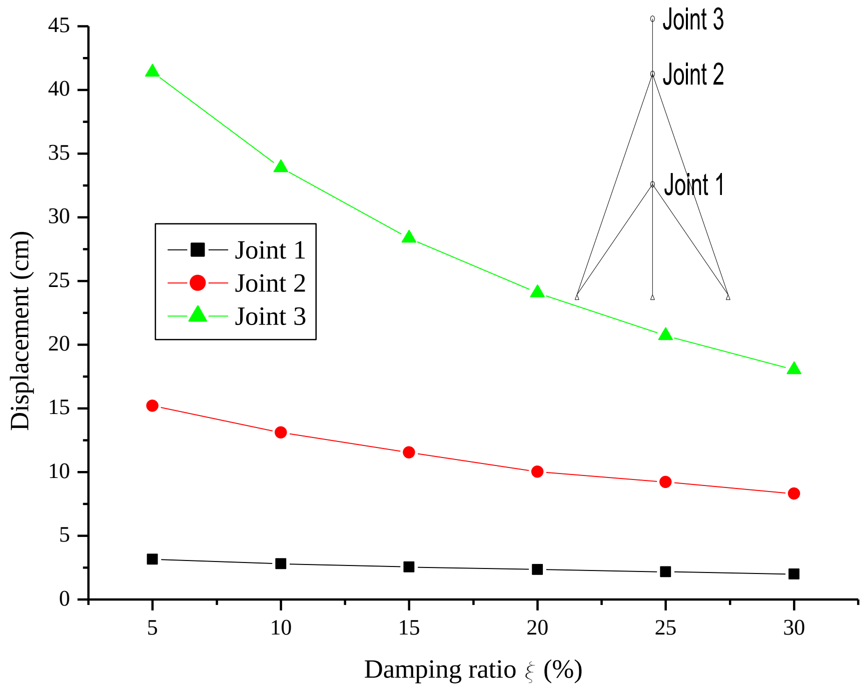

Figure 15. Variation of displacements with damping ratio.

Natural modes of vibration (first three eigen forms and associated eigen periods) are presented below.

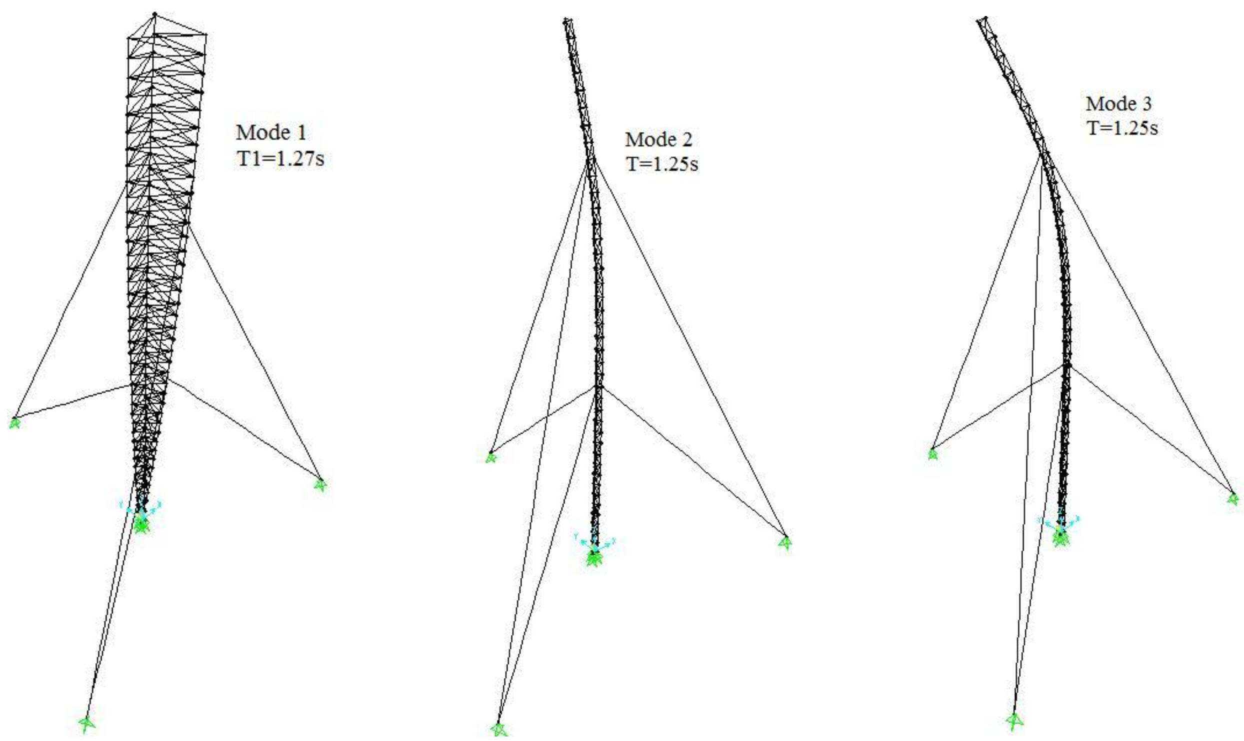

Figure 16. First three natural modes of vibration

4. Concluding remarks

As it has been mentioned, the contribution focuses on the mitigation effect on seismic behaviour via supplemental damping. A correct understanding may be achieved and relevant conclusions may be inferred only if the high level of initial tension in the cables is taken into account. The large percentage of initial pretension (33% of ultimate cable tension) has been adopted in the present paper in order to avoid complete loose of tension during strong winds. It has to be mentioned that, usually, only a 10% of cable ultimate tension is used as initial tension (pretension) in the cables [8,9]. Under this high level of pretensioning, the variation in the values of tensions in cables with damping is small as it may be seen in Table 1.

Table 1: Variation in tension values in cables versus damping level

Damping level / Cables	Tension in cables [kN]					
	5%	10%	15%	20%	25%	30%
Anchorage level + 40.00	377.8	371.72	366.94	362.99	359.62	356.92
Anchorage level + 80.00	434.71	419.34	407.38	307.67	389.68	382.99

Regarding the mitigation effect, a relevant reduction in (displacements) seismic response is noticed at the top end of the tower as it may be seen in Fig. 14. The high level of pretensioning reduces the mitigation effect of damping mainly, due to the relative high stiffness of the elastic supports offered by the cables to the tower at the anchorage levels.

An important aspect of seismic mitigation via supplemental damping is the length of time over which the mitigation effect extends. It may be noticed from Fig. 6 to Fig. 14 that this interval is about 2.5 times longer that the value of T_1 – the fundamental eigen period of vibrations, while in the absence of supplemental damping – as it may be seen in Figure 5 - this interval is 4 times T_1.

3. References

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Penthouse Steel Structure for a Five Story Building – Extension of the "Sigma" Office Building, Cluj-Napoca, Romania

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Abstract

The article describes the designed structural solutions to extend an existing five storey office building with an additional level in the city of Cluj, Romania. The existing building has a concrete framed structure and was in use during the intervention time. Using a light steel structural solution, the structure will overcome the in situ technological constraints due to the position of the existing building and the internal activity of the fifth floor. There is limited access due to the fact that the building is located close to a main road in the city with frequent traffic jam and the existing neighbor buildings are connected to the extended one along two sides. Also, the existing weak roof structure makes more complicated the connection of the new structure. Taking into account the above mentioned restrictions, the article describes the applied structural solutions which will make the structural steelwork erection possible. The designed structural solution using steel ensured the extension without refurbishment of the existing building structure and without to suspend the activity of those companies, which was located in the extended building. The paper emphasizes the particular aspects of the design process of an extension work, and summarizes technical and economical performances of the intervention.

Rezumat

Articolul descrie soluţiile tehnice adoptate în vederea realizării extinderii unei clădiri de birouri cu cinci etaje cu un nivel suplimentar, localizat în oraşul Cluj. Clădirea existentă avînd structură în cadre din beton armat, a fost în plin proces de exploatare pe toată durata intervenţiei. Utilizînd soluţii structurale uşore din oţel, a făcut posibil depăşirea constrîngerilor tehnologice şi neîntreruperea activităţii la etajul cinci al clădirii pe durata intervenţiei. Clădirea existentă ce face subiectul intervenţiei este lipit pe două laturi de clădiri existente şi se situează în apropierea unei artere rutiere cu trafic intens. Deasemenea, structura acoperişului existent realizată din chesoane subţiri a făcut mai dificilă ancorarea structurii noi de cea existentă. Cu toate acestea, extinderea clădirii cu încă un nivel adiţional s-a realizat cu succes, fără întreruperea activităţii din clădire şi fără consolidarea structurii existente. Articolul prezintă aspectele particulare ale procesului de proiectare şi evidenţiază performanţele tehnice şi economice ale soluţiilor proiectate.

Keywords: penthouse steel structures, refurbishment, technical and economical performances

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1. Introduction

The article describes the designed structural solution in order to transform an existing five storey building into a six storey building in the city of Cluj, without any intervention on the existing structure. The existing building has a framed structure with in situ poured concrete columns and transverse beams and precast concrete longitudinal beams. Due to the previous function of the building (industrial building, built in 1977-1978), the intermediate floors are realized locally with on site poured concrete solution (heavy loading) and precast concrete bottom ribbed elements.
The extension imposed to use light solution, for this purpose steel structure have found suitable. Respecting the 6,00x6,00 m concrete column raster, the geometrical dimensions of the proposed over roofing resulted 18,00x 78,00 m (width x length). The existing roof level was at +23.25 m from ground floor level. The extension on the sixth floor consists of the office area - 1404 m^2 (18 x 78 m) and the necessary annexes (stairs, elevators, access etc.). The scope of works included the following main requirements:

- To extend the existing building in order to maximize the rentable office area;
- To disturb as less as possible the existing activity;
- To avoid roof leakage during the intervention;
- To extend the structure without any refurbishment of the existing concrete structure.

In that condition, the design team needed to fulfill a list of constrains like:

- The given size of the roof, maximization of rentable area were possible only with local increase of plane dimensions of the extension;
- Limited access to the fifth floor offices, this imposed a quick and easy to apply fixing solution for the extension structure;
- All time waterproof, which imposed water tightness of the structural connection to the existing roof;
- Limited capacity reserve of the existing concrete structure and foundations, the extension was possible only keeping the supplementary loads below the capacity reserve limit;
- One side access to the roof imposed to fit the structural design to the site conditions with a corresponding erection technology

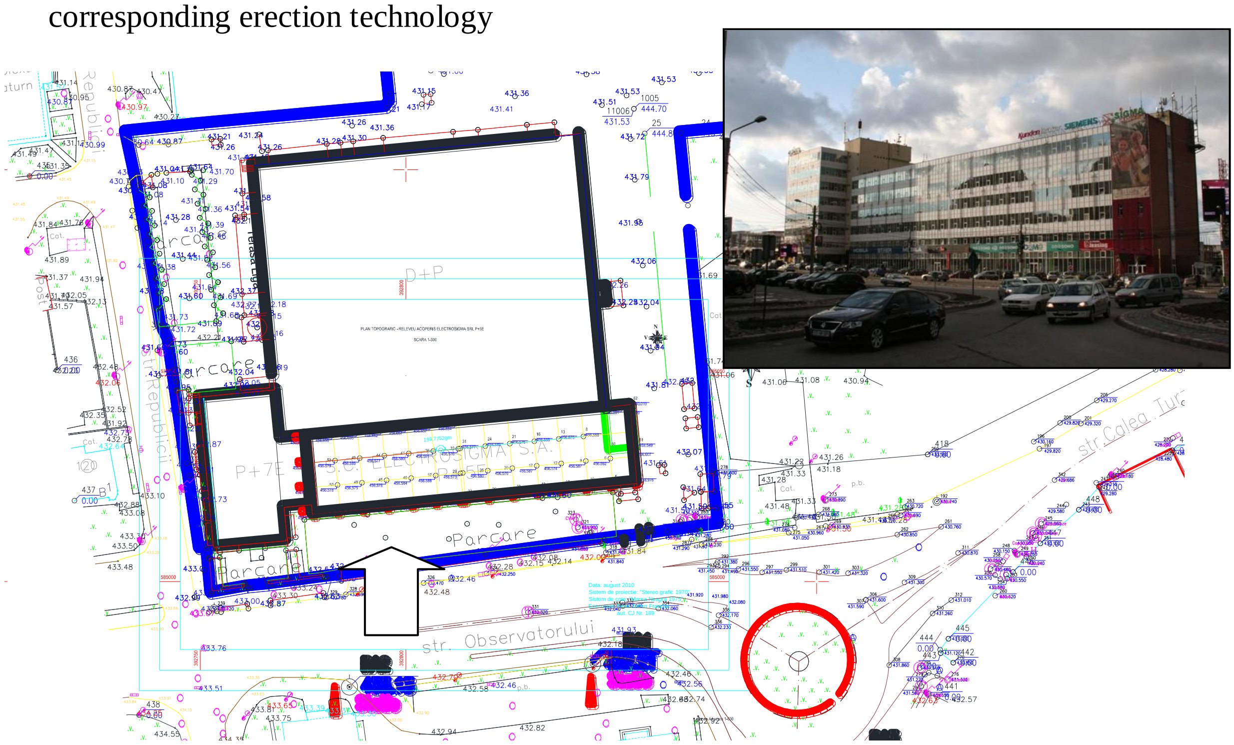
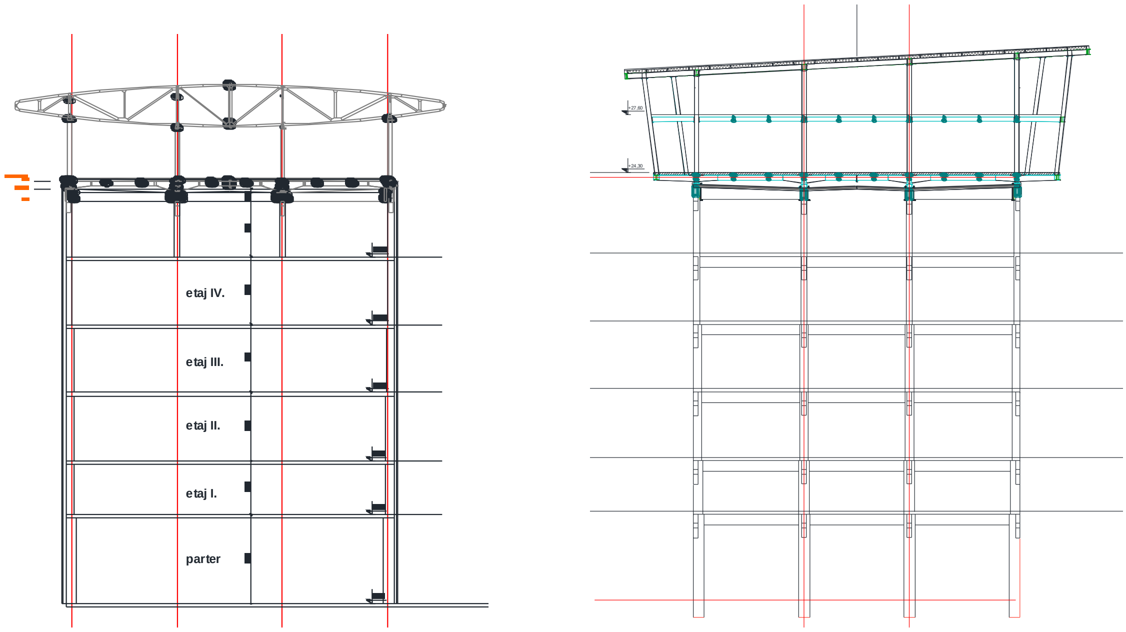


Figure 1. The site conditions (arrow indicates the access side)

2. Detailed description of the penthouse structure

2.1 The steel structure

The primary load-bearing structure of the extension was aligned to the existing concrete column raster positions. Due to architectural reason, the roof was designed with a special shape (see Figure 2.) in order to improve the "industrial" look (see Figure 3.). The transverse steel frames are based on a 6.0 m grid. The roof girders covers the width of the building with additional 2,50 m extension on both sides (fig. 2.a). Fixed base connections for the frames have been chosen. To avoid excessive loading of the existing weak roof floor structure (built with precast reinforced concrete bottom ribbed elements) and to avoid bending moments from the penthouse column bases, imposed a totally new supporting structure for the extension, serving as an interface between existing and new structure. Having a special shape of the existing roof, all the assemblies decided to made from welded steel sections. A structural steel with S355 steel grade (f_y=355 N/mm^2) have been used.
In order to create a stiff structural element between existing and new structure, for the sixth floor slab in situ reinforced concrete solution was applied. For the composite action of steel and concrete, welded shear studs have been used on floor beams. To maximize the extension area, a dry intermediate floor has been added around the elevator and access area (fig. 2b).



a. **b.**

Figure 2. Current section (a) and additional dry intermediate floor (b)

2.2 The building envelope

The standing seam roofing solution makes it possible to ensure the water tightness of the special shaped roof. Adequate thermal insulation of the envelope was necessary to optimize the heating cost of the extension. On the roof 150 mm thick rock wool insulation is laid down on the supporting deep trapezoidal steel profiles, waterproofing is assured by standing seam steel roofing.
Large glazing of the facade combined with the additional extension of the roof protects the occupants in summertime from the overheating.
The supporting structure of the facade is a steel framework of rectangular hollow sections. Local centrally placed skylights cut out of the roof to bring daylight down to the office area.

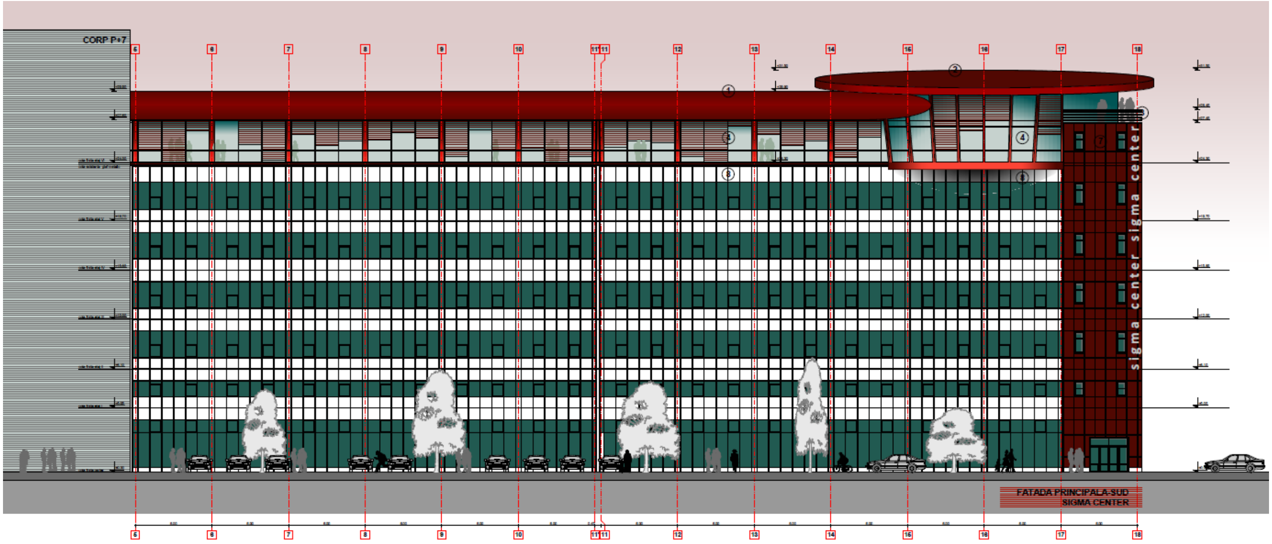


Figure 3. Façade of the building from access side.

3. Structural design aspects in case of intervention works

In case of building extensions, designers must handle the following problems:

- Evaluation of capacity reserves for the existing structure and foundations
- Appraisal of on site conditions
- Site access
- Collect the list of constrains and take care of it in the design process
- Manage the implications due to intervention (proactive instead of reactive approach)

Following chapters will show the application of this list of concept in this particular case.

3.1 Evaluation of existing capacity reserves for the structure and foundations

One of the most important aspects in case of intervention over an existing building structure is to have a proper evaluation of the capacity reserves. This activity involves a data collection about the existing structure (existing documentation study, on site measurements, tests and structural appraisal). To have a reasonable response to the mentioned aspects, a global structural analysis has been performed, taking into account the collected data about the existing structure and considering the future extension.

In order to evaluate the global structural response, in the design process the following loads have been considered (characteristic values):

- Live loads on floors u_k= 3 kN / m^2
- Snow loads on the roof according to CR 1-1-3-2005 , $s_{o,k}$=1.5 kN/m^2
- Wind loads on building envelope according to NP-082-04, q_{ref}=0.4 kN/m^2
- Seismic action according to P100-2006, with peak ground acceleration a_g=0.08g and control period of seismic motion T_c=0.7 sec
- Load combination for ultimate limit state (ULS) and serviceability limit state (SLS) according to CR-0-2005.

The design of the steel structure has been performed following the Romanian code STAS 10108/0-78. For strength, stability and stiffness requirements of the structural elements the prescription of SR-EN1993-1-1, SR-EN1993-1-8 and P100/2006 were used also. Fortunately, Cluj-Napoca being located on a low seismic zone (lowest on the Romanian territory), the influence of the extension on the existing structure was quite low consequently no supplementary interventions being necessary.

In this particular case, the capacity reserves of the existing structure represents one of the major constraints in the design process. Because the load bearing capacity of the existing roof was fairly low a steel-concrete deck was proposed as a base for the extension. In order to keep under control the reaction loads over the existing frames, pinned connections for the new floor structure were chosen. The structural configuration of the extension was based on a main frame made on vertical columns supporting an elliptical truss. Although 2 lateral columns would have been enough for the roof support, four columns on a raw were provided, in order to counterbalance the efforts on the existing concrete frame. The transverse girders have been extended on both sides outside of the building, both from architectural and structural considerations. It has been obtained in that way a uniform distribution of the loads in the existing columns. A suitable horizontal and vertical bracing was provided in order to control structural flexibility, eigen values and deflections of the extension structure. Longitudinal girders, along the column line, were disposed in order to improve the lateral buckling resistance of the transverse girders.

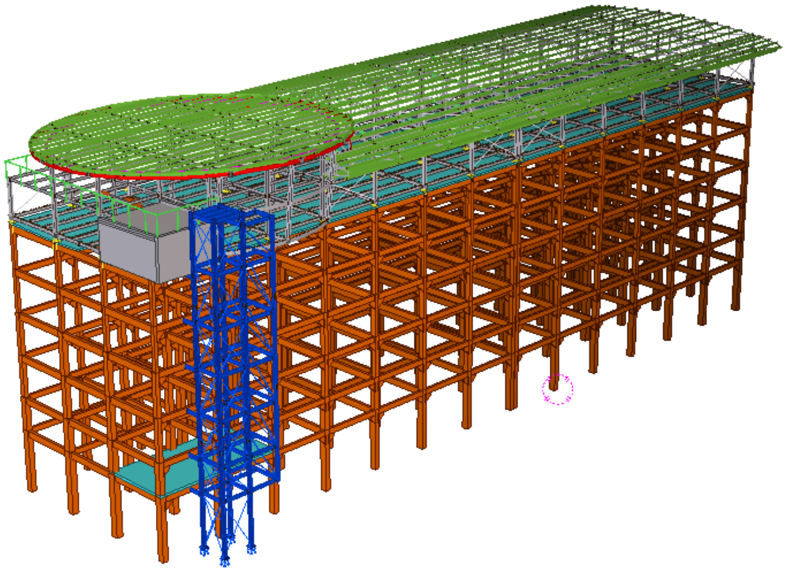


Figure 4. Façade of the building from access side.

To express the penthouse building structural performances, the following results are relevant:

- Eigen period on transversal direction (building A) = 1.35 sec
- Eigen period on transversal direction (building B) = 1, 35 sec
- Eigen period on longitudinal direction (building A) = 1,30 sec
- Eigen period on longitudinal direction (building B) = 1,25 sec
- Steel consumption index for the interface structure = 32 kg /m^2.
- Steel consumption index for penthouse structure (building A) = 32 kg /m^2.
- Steel consumption index for penthouse structure (building B) = 38 kg /m^2.

3.2 Appraisal of on site conditions

The design of the final solution needs to consider the on site conditions. The decided intervention will generate different solutions in case of a totally evacuated building and for a building in use during the intervention. For a totally evacuated building, there is reasonable constrains in terms of intervention mode, time, location, infiltration etc. In case of a building in use during the intervention, the structural solution needs to consider the activity, which should be disturbed in the intervention area. For this particular case, due to the continuous activity in the existing building, the designed solutions imposed quick and easy to apply fixing solution for the structure of the over roofing, because the intervention on inside was possible only out of the office hours (night and weekend) and with respect of very strict security conditions. Also the intervention was accepted only with minor damages and clean technologies, in order to be possible to maintain a quick cleaning process after the applied solutions.

3.3 Site access

In the design process of the final solution needs to take important decisions concerning to execution technology. This will be strong connected to the site access, which needs a carefully study of the site plan, where the building is located. In this particular case, due to the access from only one side (see figure 1) it was necessary to place the crane in a position to use as less space as possible along the free side and in the same time to cover as much as possible from the intervention area. In this way the free side was possible to use also for site organization, being impossible to create other options for crane placement and site organization in this particular case.

3.4 Managing the constrains

For such type of design works, it is very important a proper management of the collected constrains. Usually the involved actors have different expectations, placing the designer in a very difficult position: even the resistance and safety are the main goal; each involved actor will evaluate his own position according to the circumstances: “designer want safe connections, but user don’t want dust, dirt, noise and suspended activity”. It is important to notes that in such kind of projects also the actual user of the building is “part of the project” and needs to be included in the whole communication process. With proper communication, it was possible to maintain divergences and to obtain acceptance of the implicated actors.

3.5 Proactive approach

Depending by the site conditions is recommended to evaluate the impact over the direct exposed and neighbor area: the occupants of the building are directly exposed to have negative experiences due to the intervention. But dust, noise pollution could have negative impact over the direct exposed neighborhood. Traffic necking in case of important road routes should disturb the traffic on the whole city level, due to that site is located close to a place with frequent traffic jams. For those sites is good to have prepared strategy: what and how to proceed in case of foreseen problems?

4. Erection process and follow up

One of the most challenging activity was the erection of the main structure. Due to permanent activity inside of the building, water tightness requirement of the roof it was the major concern. That imposed clear detailing work of the structural connections to the existing structure, not only in terms of resistance. The joints to the existing structure have been designed in a way to facilitate the required structural safety, water tightness and a proper erection (figure 5). The new interface between existing and extension structure served as support for the extension works. For this operation the site placed 10 tones capacity crane was used. This was followed by the erection of the sixth floor structure (see Figure 6). Once the structure was erected, all other specialty work was possible to perform. A very important component of the whole process was the site follow up: during the execution process, each connection detail was carefully checked, in order to ensure the way of load transmission to the existing structure similarly as it was considered in the structural analysis.

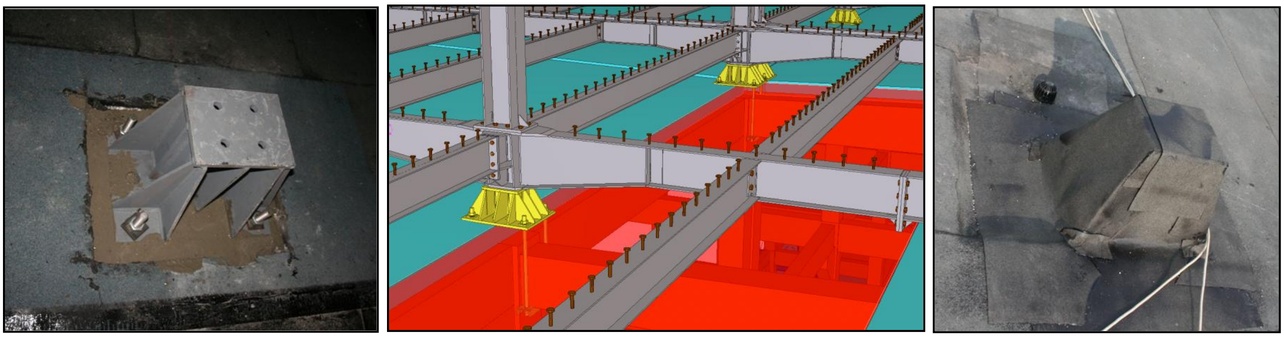


Figure 5. Structural connection existing and extension structure

Figure 6. Structure during erection.

5. Conclusions

The paper illustrates the successful application of the steel structure for the extension of a multi storey building without any refurbishment work. A wide range of design parameters are briefly summarized. The paper emphasizes the particular aspects of the design process of an extension work, and why such projects differ in many ways from Greenfield investments. The paper shows the importance of some particular aspects of the design process like: evaluation of existing capacity reserves for the structure and foundations (1), appraisal of on site conditions (2), importance of site access (3), proper management of constrains (4) and proactive approach during intervention works (5). The authors applied successfully a set of particular structural solutions and handled unusual design situations which cannot meet in current practice. The evidence is the final building (see figure 7) and was demonstrated by the obtained technical and economical performance, described in this paper. This case study is a good example of holistic role of structural engineering in the design process in a changing world; confirming a step forward in merging of architecture, structural engineering and other specialties (not exclusively engineering).

Figure 7. Intermediate and actual stage of the building.

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Weight Minimization of Trusses with SGA and PGA

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Abstract

This article describes the implementation of SGA (simple genetic algorithm) and PGA (parametric genetic algorithm) in an optimization program. Optimization program was developed in MATLAB. The objective function for the optimization problem is represented by the structure's weight; the constraints of the problem are represented by the displacements and stresses. The variables optimization problems are sectional areas and / or node coordinates. Displacements and strains in bars were calculated with FEM. The results were compared with results obtained by other authors.

Rezumat

Acest articol descrie implementarea SGA (simple genetic algorithm) si PGA (parametric genetic algorithm) intr-un program de optimizare a structurilor cu zabrele. Programul de optimizare a fost elaborat in MATLAB. Functia obiectiv pentru aceste probleme de optimizare este reprezentate prin greutatea structurii, iar restrictiile problemei sunt reprezentate prin deplasari si tensiuni. Variabilele problemelor de optimizare sunt ariile sectiunilor si/sau coordonatele nodurilor. Deplasarile si tensiunile din bare au fost calculate cu MEF elaborata in. Rezultatele obtinute au fost comparate cu rezultatele obtinute de alti autori.

Keywords: structural optimization, genetic algorithm, trusses,

1. Introduction

A great deal of attention has been paid out to genetic algorithms due to their potential becoming a new method of optimization. Among the advantages using this type of methods one can enumerate: simple manner of approaching the problem, the flexibility and the precise response to changing circumstances (1).

The optimization algorithm described is composed using MATLAB and it is based on Haupt's code and on the one predefined in MATLAB, slightly modified to be able to work with both discrete (profiles, cross sections) and continuum(nodes, pre-tensioning forces) variables. For PGA I implemented a function which changes the number of individuals created by crossover and mutation functions according to the obtained solutions.

The optimization function is an iterative process which contains nine steps for SGA, respectively ten steps for PGA.

1. Determination of the number of parents necessary to create a new generation
2. Elite selection
3. Scaling the fitness value

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4. Parent selection
5. Creation of the individuals through cross-over
6. Creation of the individuals through mutation
7. Creating a new generation
8. Fitness value calculation for each individual
9. Finalizing condition check
10. Changing the PGA parameters

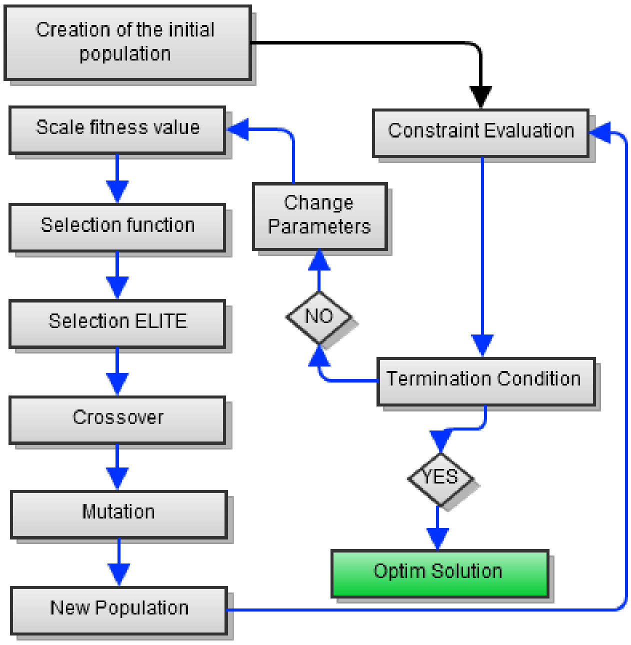

Figure 1. Flowchart for SGA and PGA

In structural mechanics a structure is defined by J.E.Gordon (2) as "any assemblage of materials which is intended to sustain loads". Optimization is a process through which an initial product is transformed into a better product using several restrictions.

2. Optimization program (GA)

The structural optimization algorithm is written in MATLAB code based on evolutionary theories (genetic algorithms). The objective function (1) is represented by the weight of the structure, and the imposed restrictions are deflections (2) and tensions (3). The operator which creates the initial population and which is also used for mutation, was elaborated by the author to generate real and integer numbers, and the rest of the operators: scaling, selection and cross-over are from MATLAB library. A decoding function and a parameter (mutation ratio, number of individuals created using cross-over function) changing function was written.

$$f_o = \sum_{n=1}^{elemente\ nr.} l_n \cdot A_n \cdot \delta \qquad (1)$$

Where: $l_i -$ *element length* n

$A_n -$ *section area for element* n

δ – *material* self weight

$$|\sigma_{elem}| \le \sigma_{adm} \qquad (2)$$

$$|[u,v,w]_{elem}| \le [u,v,w]_{adm} \qquad (3)$$

Where: $\sigma_{elem} -$ *element axial tension*

$[u,v,w]_{elem} -$ *deplasarile nodale dupa coordonatele globale*

$\sigma_{adm} - tensiunea\ admisibila$
$[u, v, w]_{adm} - deplasari\ nodale\ admisibile$

2.1 Fitness Function

The fitness value of an individual from a genetic algorithm process is provided by (4) which contain the objective function. The fitness function has three stages; the first one is decoding the individual in order to input the data into the structural analysis program; the second one is where the objective (structure weight) function is being calculated and the penalty coefficient is being evaluated according to imposed restrictions.

$$f_f = f_o \cdot (1 + p^2) \qquad (4)$$

Where: $f_f - fitness\ function$
$f_o - objectiv\ function$
$p - penalty\ coefficient$

2.2 Initial Population

The initial population creating function has two primary steps. In the first stage natural values will be generated for the variables which represent element cross sections (profiles), following the generation of real number for the nodal coordinates and pre-tensioning forces. After finalizing this process begins the evaluation of the individuals from the created population, and after this step the process continues with the iterative stage.

2.3 Mutation

The mutation process consists in randomly electing several genes of an individual and replacing them with a number that respects the interval imposed by the user. This function contains the mutation parameter which represents the maximum number of variables that can be changed. In AGA process this parameter modifies according to obtained solutions.

2.4 Encoding Function

The program uses two types of encoding of the variables based on what they represent in the structure. The first type represents discrete values from the natural numbers, i.e. elements from a database (cross-sections). The second type is defined on a continuous domain (real numbers) and is representing the nodal coordinates. When variables are defined, the type each variable is also determined. The algorithm organizes these variables in vectorial elements which represent individuals which are grouped in generations.

2.5 Change function for parameters in the optimization program

This function evaluates the convergence of the optimization problem, and if for "n" consecutive generations the global optimum is unchanged then the number of individuals created by the mutation function increases in order to investigate new areas. Once found the new global minimum the parameters will tend linearly towards the initial values for investigating the area in question. Parameters progressively change their values between minimum and maximum.

The genetic scaling, selection and cross-over operators are the ones predefined in MATLAB library which are: operator rank scaling, stochastic uniform selection and two point crossover.

2.6 Structural analysis module

Structural optimization problems are limited to certain restrictions, which can be represented by tensions and deflections. The elaborated program calculates the bar tensions and the nodal displacements based on finite element method. The analysis program of planar and spatial lattice girders is according to the one in MATLAB library elaborated by M. Asghar Bhatti, but has slight modifications (3).

3. Numerical results

Each problem has been run 4 times using the SGA and PGA method. After the four runs was accepted the reference solution with the minimum fitness value. The maximum number of generations is 250 and the number of individuals per generation is 100.

3.1 Plane truss, 9 bars

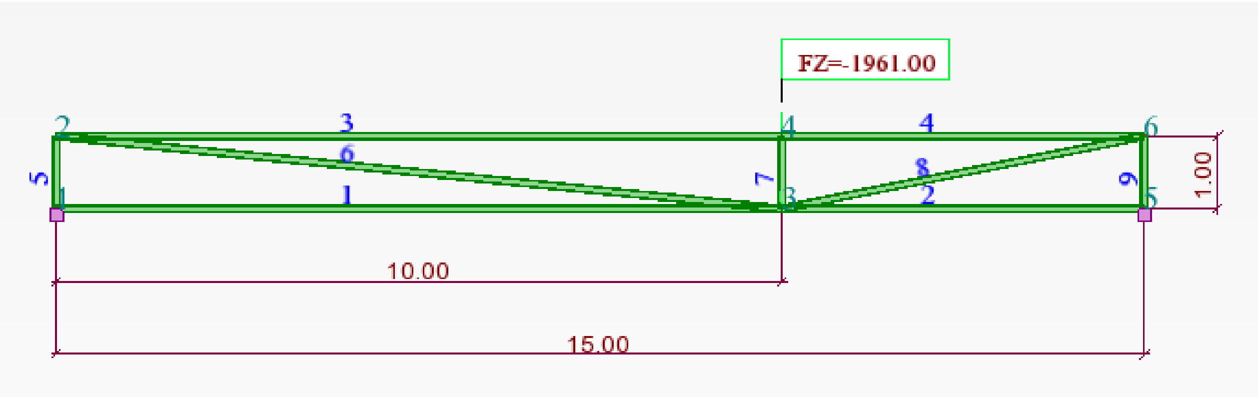

Figure 2. Plane truss

The plane truss consists of 6 nodes and 9 bars as illustrated in figure 2. The used metal consists of steel having the modulus of elasticity 205.93GPa. The structures is loaded with a vertical force Fz=-1961.31 kN in the third node. For the structural optimization, from the volume point of view, some restrictions are imposed over the bars tensions: the maximum tension accepted for compression and tensile is 980 daN/cm2. The optimization problem uses 14 variable elements representing the nodes coordination (nods 2, 6 after the x,y axes and node 4 after the y axe) and the bars properties (arias) (9 elements). The variables represented by arias are chosen from a discrete set: {1,2,3,…,178,179,180} cm2. The boundaries imposed over the variables are detailed in Table 1. For this problem the objective function was divided by specific weight of the material, the structural volume being minimized.

Tabel 1. Variable domain

	V1	V2	V3	V4	V5	V6	V7	V8	V9
	N2 x	N2 y	N4 y	N6 x	N6 y	A1	A2	A3	A4
LB	0	-0.5	-0.5	-4.5	-0.5	1	1	1	1
UB	9.5	8	8	0	8	180	180	180	180

	V10	V11	V12	V13	V14
	A5	A6	A7	A8	A9
LB	1	1	1	1	1
UB	180	180	180	180	180

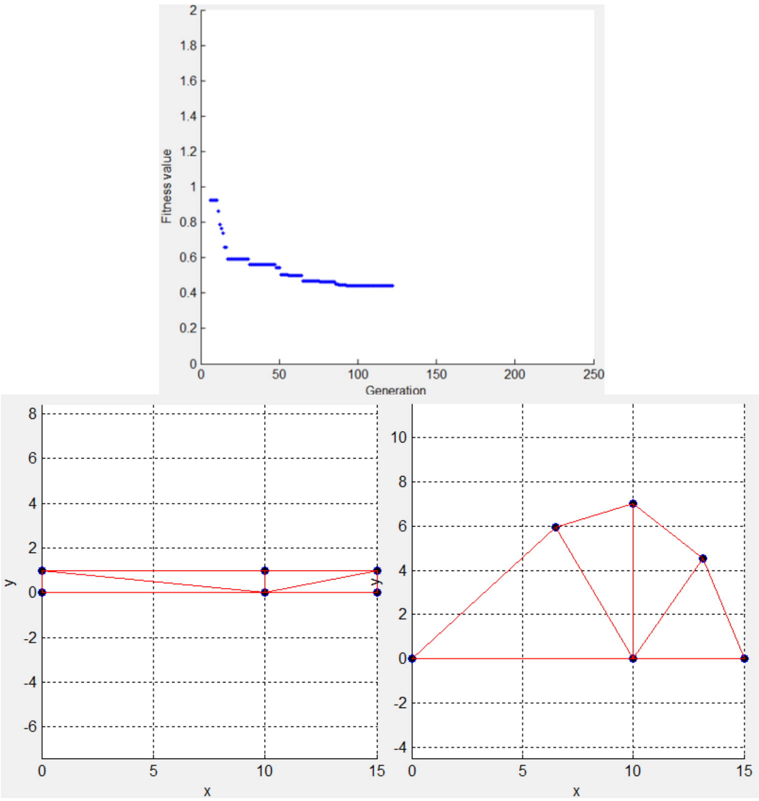

Figure 3. Optimization process and optimal solution

After solving the two problems, the results were compared with the results obtained by Ismail Farajpour, in this article (4). For solving the optimization problem, the author Ismail Farajpour, used the "descending directions" method, which is part of "one-at-a time" category. The main advantage of this method is represented by the simplicity of the iterative process. In case of problems with several variables, the process consists of solving sets of sub problems. Each sub problem improves the solution depending on the chosen variable, the rest remain fixed (4).

Tabel 2. The solutions obtained by solving the two problems and Ismail results

Variables	Results SGA	Results PGA	Ismail (4)
nod 2 - x	6.48	1.267	4.062
nod 2 - y	4.92	-0.149	4.952
nod 4 -y	6.02	5.293	6.068
nod 6- x	-1.836	-1.402	-0.797
nod 6 -y	3.543	2.814	3.203
A1	7	1	45
A2	29	51	25
A3	111	127	96
A4	122	137	114
A5	102	124	81
A6	57	15	69
A7	116	149	82
A8	86	96	98
A9	147	145	136
Volume [mc]	0.441	0.452	0.46

3.2 Plane truss, 10 bare

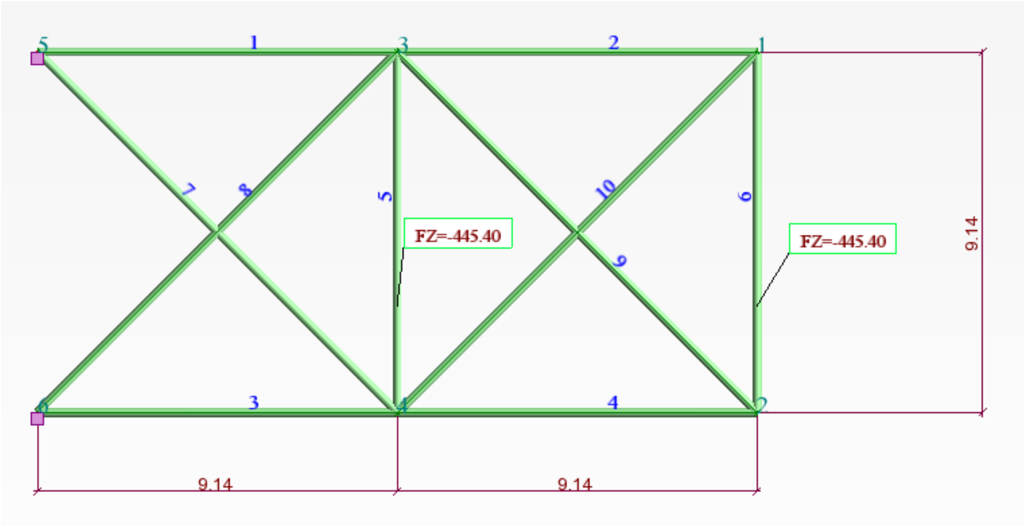

Figure 4. Plane truss

The plane truss consists of 6 nodes and 10 bars as illustrated in figure 4. The used metal consists of steel having the modulus of elasticity 68.95GPa. The structures is loaded with two vertical forces Fz=-445.40 kN in the third and 4th node. For the structural optimization, from the weight point of view, some restrictions are imposed over the bars tensions and displacements: the maximum tension accepted for compression and tensile is 1723 daN/cm2, and the maximum displacement is 5.08cm. The variables elements are represented by the bars properties (arias) (10 elements). The boundary conditions imposed over the variables are detailed in table 3.

Tabel 3. Variable domain

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
LB	1	1	1	1	1	1	1	1	1	1
UB	42	42	42	42	42	42	42	42	42	42

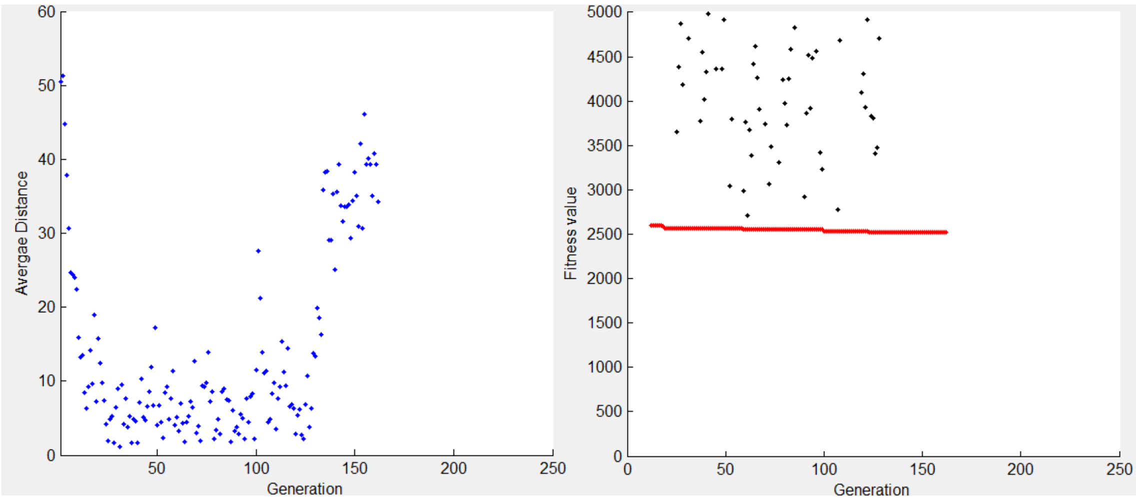

Figure 5. Solution diversity in each generation and proses convergence

The researcher Li, in 2009, proposes the heuristic method HPSO (heuristic particle swarm optimization) for solving the optimization problems. This method is based on standard method PSO and „harmony search" (HS), applied in a discreet area (5).

After solving the problem using the 2 resulted methods, the solutions were compared with the article (5).

Tabel 4. Obtained solutions and comparisons

Variables	SGA	PGA	Li (5)
A1	193.56	216.14	193.5
A2	10.45	10.45	10.449
A3	141.94	141.94	147.705
A4	100.01	100.01	87.075
A5	10.45	10.45	10.449
A6	10.45	10.45	10.449
A7	46.58	51.42	51.4065
A8	170.98	141.94	170.925
A9	141.94	147.75	141.9
A10	10.45	10.45	11.61
Weight [kg]	2506	2497	2508

3.3 Spatial truss, 25 elements

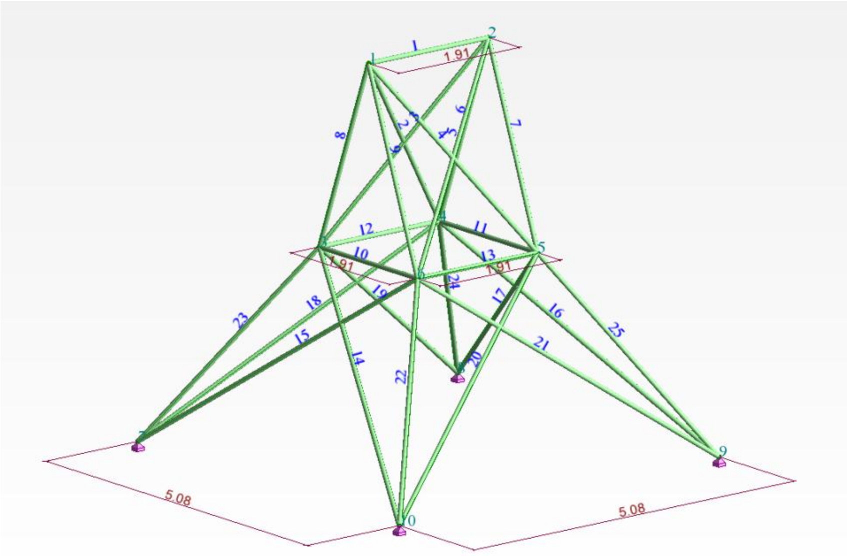

Figure 6. Spatial truss 25 elements

The spatial truss is composed by 25 linear hinged elements, as illustrated in figure 6. The material density is 0.0028 kg/cm3, and the modulus of elasticity is 689475 daN/cm2. For the optimization problem are imposed 2 restrictions: the tension in bars (2757 daN/cm2) and the displacement nodes 0.89 cm. The elements arias are grouped into 8 categories:

- Group 1 bar nr. 1
- Group 2 bar 2 3 4 5
- Group 3 bar 6 7 8 9
- Group 4 bar 10 11
- Group 5 bar 12 13
- Group 6 bar 14 15 16 17
- Group 7 bar 18 19 20 21
- Group 8 bar 22 23 24 25

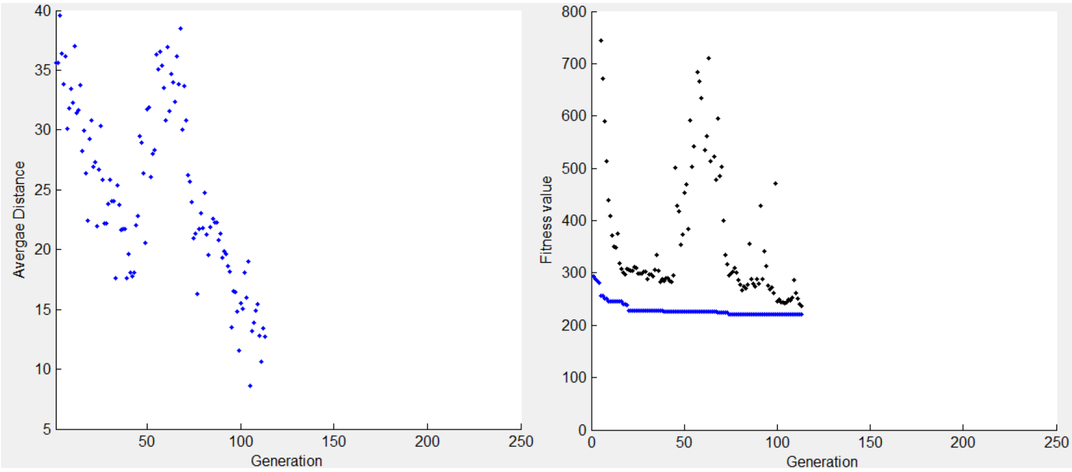

Figure 7. Solution diversity in each generation and proses convergence PGA

The method used by Kaveh is called Big Bang and Big Crunch, and has been introduced by Erol and Eksin. This method has a high computational time and a high convergence speed. The optimization method generates random points during the Big Bang, and the Big Crunch phase reduces these pointes to a representative point around the center of gravity. After a number of iterations, the random distribution from the search area in Big Bang phase is restricted around the determined average point, the algorithm converging into a solution (6).

Tabel 5. Obtained solutions and comparisons

Variables	SGA	PGA	Li (5)	Rajeev (7)	Tayfun (8)	Talaslioglu (9)	Kaveh (6)
A1	0.65	1.29	0.645	0.645	0.645	0.645	0.065
A2	1.94	1.94	1.935	11.61	1.935	0.645	12.856
A3	20.65	21.290	21.93	14.835	21.93	21.93	19.717
A4	0.65	0.65	0.645	1.29	0.645	0.645	0.065
A5	9.68	10.32	13.545	0.645	13.545	12.255	0.065
A6	6.45	7.1	6.45	5.16	6.45	6.45	4.293
A7	7.1	3.87	3.225	11.61	3.225	4.515	10.594
A8	20.65	21.94	21.93	19.35	21.93	21.93	17.281
Weight [mc]	227.08	221.71	219.92	247.6	219.92	220.4	247,28

3.4 Spatial truss, 120 elements

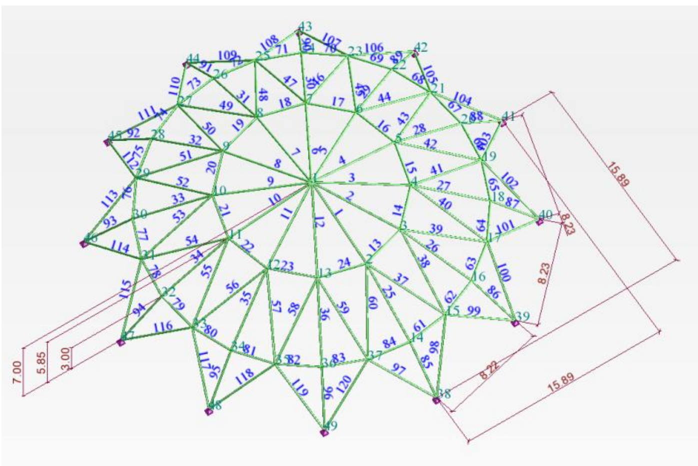

Figure 7. Spatial truss 120 bars

The spatial truss consists of 49 nodes and 120 bars as illustrated in figure 3.7. The used metal consists of aluminum having the modulus of elasticity 210GPa. The structures is loaded with: 60kN in node 1, 1430kN in node 2 and 10kN in rest. For the structural optimization, from the weight point of view, some restrictions are imposed over the bars tensions and displacements. The tensions verifications are according to AISC ASD [art 6], admissible resistance is 4000 daN/cm2, and maximum displacement is 0.5cm. The variables elements are represented by the bars properties (arias) (7elements).
The variables for the problem 4a are represented by the bars sections, which are filled into 7 groups.

Tabel 6. Obtained solutions and comparisons

Variables	SGA	Kaveh (10)	Lee and Geem (11)
Z1	2.85	-	-
Z2	1.98	-	-
Z3	1.14	-	-
A1	15.222	21.35	21.44
A2	36.443	22.17	21.73
A3	25.607	26.74	26.54
A4	10.256	18.25	17.95
A5	10.776	4.99	5.01
A6	25.607	22.40	21.56
A7	6.082	16.45	15.82
Weight [mc]	6233	8840	8898

3. Conclusion

By running the optimization program developed by the author were obtained optimal solutions for problems 1 and 2, and for the third problem the obtained result has the same value as in the studied article.

Mostly, the SGA method generated worse results than the PGA method, but for most processes performed using SGA, the number of iterations was lower than those performed by PGA.

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Active, Semi-active and Hibrid Control Systems Properties and Applications

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Abstract

This paper presents the characteristics of different type of seismic isolation systems such as active, semi-active and hibrid control systems and an example of such systems found in different types of buildings in Japan and China. Because passive systems have limited performance, have developed alternative control systems to overcome their disadvantages, as active, semi-active and hibrid systems.

Rezumat

Una dintre cele mai importante preocupari ale inginerilor proiectanti in zilele noastre este de a gasi cat mai multe solutii pentru perfectionarea acestor sisteme de izolare seismica, devenind cat mai eficiente, sigure si economice. Acest lucru este posibil prin atenuarea raspunsului structural al unei structuri supusa la solicitari dinamice, prin utilizarea unor dispozitive de control si algoritmi de calcul adecvati, prevenind astfel eventualele deteriorari ale sistemului structural care pot provoca tragedii umane si care au repercursiuni economice enorme.

Keywords: seismic isolation systems, earthquake, dynamic loads

1. Introduction

One of the most important concerns of today's civil engineers is to find as many solutions to improve the seismic isolation systems to become more efficient, reliable and economical. This is possible by reducing the structural response of structures subjected to dynamic loads, using appropriate devices and control control algorithms, thus preventig any damage to the structural system that can cause human tragedy and economic repercursions. Basically there are four classes of seismic isolation systems, such as passive devices that do not require external power sources and are very safe and do not destabilize the structure, but their performance is limited because the systems parameters are constant. On the other hand, there are active control devices that are adaptable to different uses and different loading conditions, but their problems are stability and are high power consumers. The third class of seismic systems are semi-active devices wich are the most promising, their advantage is that they absorb and store energy therefore they do not pass it to the structural system, [6]. And the four category are the hibrid control systems, made up of a combination of passive and active systems, using only the advantages of these systems, beeing more economical and more safety, [8], [9].

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2. State clasification

2.1 Japan

In Japan base isolation systems occupy three quarters of isolated buildings with seismic isolation systems, and only a fourth of isolated buildings are using other types of isolation systems. One of these types of seysmic isolation systems are active mass dampers. An exemple of building isolated with these type of isolators is Hankyu Chayamachi Building known as Applause Tower from Osaka (fig. 1). At the top of the building, on the roof is an heliport that sits on an active mass damper system which consists of an tunned mass dumper and elastomeric bearings with a weight of 480t and a digital control system implemented with two actuators of 5t each, which are positioned on both x and y directions, increasing the damper coeficient from 1.4% to 10.6%, [1].

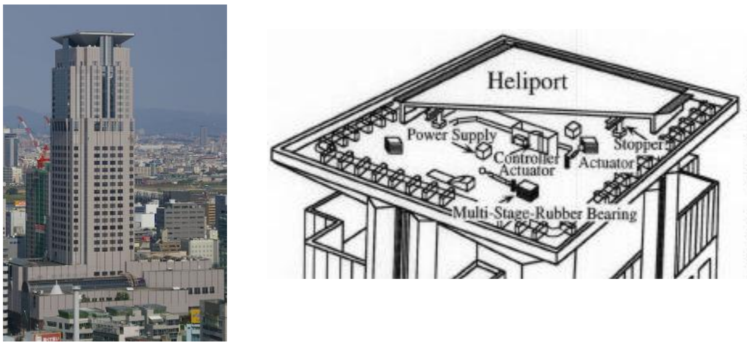

Fig. 1 - Hankyu Chayamachi Building and the heliport above with the active mass damper [1]

Another type of seismic systems is active variable stiffness. Such system will meet in the Kajima Technical Research Institute from Tokyo, (fig. 2).

Fig. 2 - Kajima Technical Research Institute

In this building are located sensors that analyze the seismic ground motions of the first floor with a motion analyzer. This information is sent forward to a control device AVS, which engages the system if the ground acceleration exceeds the level of 10cm/s2 and alerts the structure rigidity by selecting the optimum stiffness to maintain the lowest response of structure. On the sides of the building are installed inverted V bracing attached to the beams which are adjusted with a cylindrical locking device. The electrical power needed for a single device to operate is about 20W and in case of an emergency a generator is capable of sustaining the system, [1].

Building isolated with hybrid energy dissipation systems. An example of building isolated with this system is the Landmark Tower from Yokohama (fig. 3), with a height of 296m and 70 floors. The system was installed at 282m above the ground, and consists of two units each made of a three-stage pendulum active on two directions, with a spring system and actuator control system. The pendulum system has a period of 6s, and using a controller that can modify the length of the pendulum can be adjusted to values less than 4.3s, so it can include a variety of fundamental periods. Each unit has 9 square meters and is 5m high and weights 250t including the pendulum mass. The tuned mass damper was installed in the center of the structure with three frames connected by triplicated ropes. Between each frame were installed oil dampers with variable damping coefficient to ensure stability and safety of the system, [1].

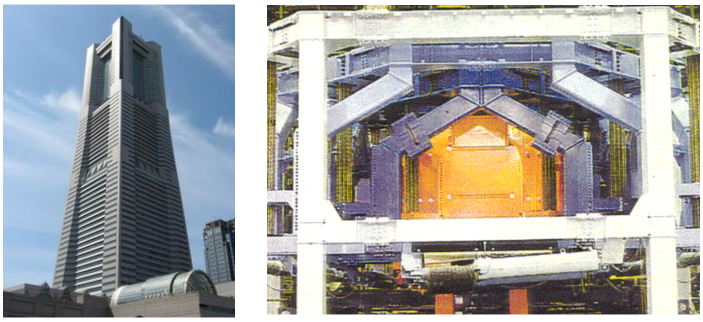

Fig. 3 - Landmark Tower and the hybrid system [1]

Another building that uses this type of system is Ando Nishikicho Building (fig. 4), wich has 14 levels. The system was installed at the top of the structure and consists of a laminated rubber bearings and oil dampers the control being achieved in two directions. Active energy dissipation system consists of an AC servo motor and ball screws mounted one above the other. Passive system weights 18t, while active system weights 2t.

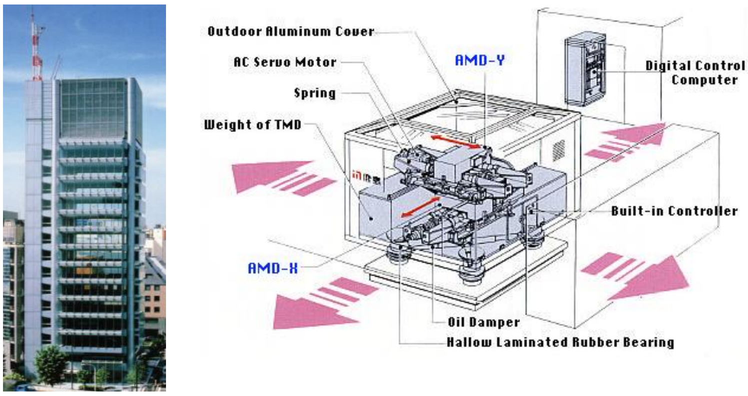

Fig. 4 - Ando Nishikicho Building with the isolation system [1]

2.2 China

An active energy dissipation system has been used in Nanjing TV Tower (fig. 5) which has a height of 340m.

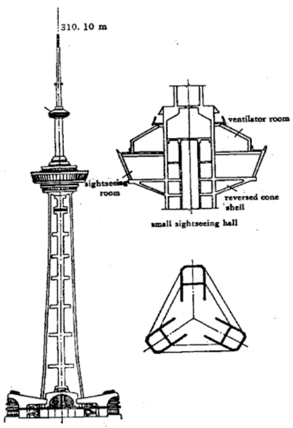

Fig. 5 - Nanjing TV Tower

Due to space limitation, initially were considered passive systems but they could not be incorporated. The system consists of a ring-shape mass, which wheights about 1% from the weight of the tower that sits on a sliding friction bearing. The ring mass is controlled by three servo-hidraulic actuators, [1].

3. Common and particularities properties of seismic isolators

3.1 Active control system

To control the vibrations of the structure were chosen initially passive control systems due to their simplicity and safety, which remain functional without an external power source but without the use of control mechanism, these devices are unable to adapt to any variations system parameters. We can get control quickly and efficiently using a system that is able to respond to changes such as active control systems. These systems consist of hydraulic or electro-mechanical actuator systems driven by a suitable control algorithm, such as closed loop or feedback in which the control forces are determined by the feedback response of the structure. Active control systems include active mass drivers, active variable stiffness systems, active gyrostabilizers, [1].

3.1.1 Active mass dampers

In case of active mass dampers, a computer analyzes the response signal and introduces a control force based on the feedback of the speed/acceleration of the structure, and the actuators acts on the secondary mass to counteract the building motion, (fig. 6). Although this systems require smaller damping masses and have higher efficiency levels rather than passive systems, they are more expensive, [1]. The secondary damping mass is composed of magnetostrictive rods surrounded by two coils. Coils are two support plates which are connected to a rigid frame through two elastic suspension arranged in parallel and mounted on the vibrating mechanical structure. A magnetic field is caused by a current I(t) in coils, which produces a tiny extension S(t) of the magnetostrictive rods along the horizontal direction. This extension is transformed by the elastic suspension in a larger motion of the total mass composed of magnetostrictive rods, coils and support plates in the perpendicular direction. The amplification of the displacement depends on the angle of the elastic suspension at the working point αo and total mass moved produces an inertia force which also has an effect on the vibrating mechanism of the structure. The elastic suspension is stiffer in the longitudinal direction and in the perpendicular direction is soft resulting a mechanically efficient model, [3].

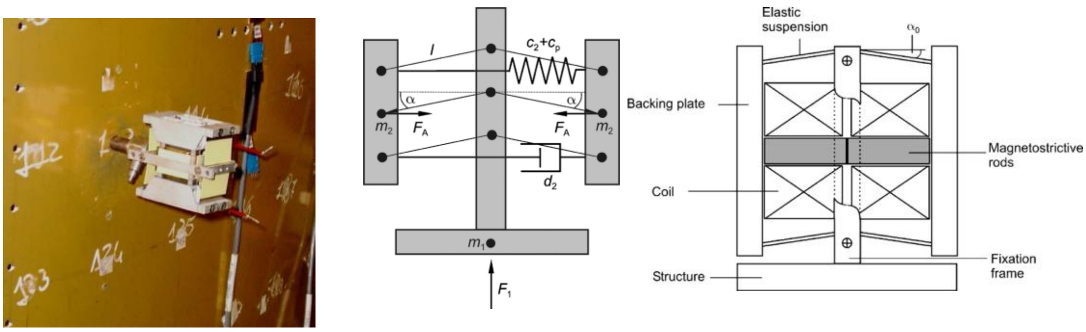

Fig. 6- Secondary active mass and the mechanical model [3]

3.1.2 Variable active stiffness

Active stiffness control system is a new alternative for active control system, which can change the stiffness of a structure in order to control its vibration, even during earthquakes. The installation consists of the introduction of inverted V shape bracing on each story at both ends of the structure in order to reduce the transverse motion. Each bracing is attached to a variable stiffness device for adjusting the stiffness, which is activated by opening a valve inside it, and when the valve is closed, the system is blocked. During the analysis of seismic movements, the control system changes the frequency response of the structure, which is achieved by locking or unlocking different bracing. Thus, the resonance behavior can be eliminated by adjusting the optimal structural stiffness, [1].

3.1.3 Other types of active systems

Active systems with tendons are prestressed tendons placed between levels of a structure, as well as bracing. They are controlled by actuators that adjust the tension in some bars, thereby controlling the magnitude of the control force applied to the structure, [2].

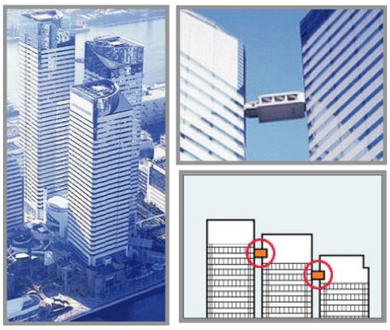

Fig. 7 - Triton Square Office Complex, Japonia

Active coupling control systems in buildings. Using this method, connecting two or more buildings with the help of actuators it can control the stiffness of an structure which helps to control the response of the other structure, [2]. In fig. 7, it is presented a building in Japan, Triton Square Office Complex, isolated with this type of system in 2001 in which the levels 45-40-35 are conected with actuators.

3.2 Hibride control system

Another effective control system is the hibrid system, which was also design to overcome the shortcomings of passive system [9], such as incapability to respond to suddenly applied forces such as earthquakes or some climate hazards.

3.2.1 Hibride mass damper

An example of such a system may consist of a passive auxiliary mass damper and a tertiary small mass connected to the secondary mass by a spring, a damper and an actuator. The secondary mass is set in motion by activating the tertiary mass which is driven in the opposite direction to the tuned mass damper, making it more efficient. The active system is used only when movements exceed a maximum admisible value of the structure, otherwise remains in passive mode. This combination of active and passive systems in Japan have been shown to reduce the structural response with more than 50%, [1].

3.2.2 Hibride liquid damper

Another type of hibrid system control is provided using fluid dampers, (fig. 8). This system consists of a tank partially filled with water, which is allowed to move while moving the structure under dynamic accelerations. The force exerted by fluid motion, resists the motion of the strucure, reducing the structural response, [4].

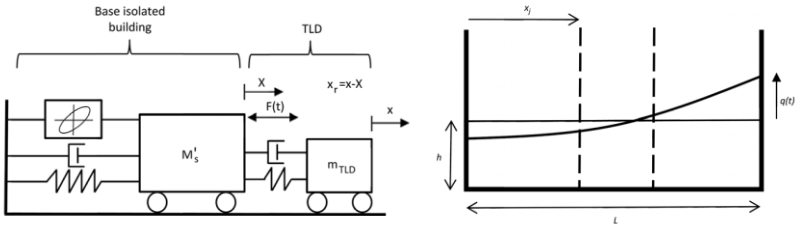

Fig. 8 – The mechanical model of tuned liquid damper [4]

The dynamic characteristics of the system are presented in (eq.1), (eq.2):

(1) $$m_{\text{TLD}} = \frac{8\rho b L^2}{\pi^3} \tanh\left(\frac{\pi h}{L}\right)$$

(2) $$\omega_{\text{TLD}} = \sqrt{\frac{\pi g}{L} \tanh\left(\frac{\pi h}{L}\right)}$$

m_{TLD} –equivalent mass
ω_{TLD} –linear angular frequency
g –gravitational acceleration
ρ –fluid density
b, L –container size
h –liquid heigh

3.3 Semi-active control systems

After intense activity for determination of more efficient seismic isolation systems, researchers have developed a new generation of control devices, semi-active control systems that combine the advantages of passive and active isolation systems. Semi-active systems can response quickly to a sudden gust front, or earthquake and provide damping, unlike to passive systems that do not work at optimum damping values for most of the time. Preliminary studies indicate that these devices can achieve the same performance levels as active systems, but without risk of destabilization or large energy requirements, the system remains operational even on battery during extreme events such as earthquakes, [1].

3.3.1 Magnetoreological/Electroreological dampers

A semi-active control method is to use magnetoreological dampers, (fig. 9) which produces high damping forces, which consists of a cylinder piston that acts on fluid generating it movement, [2]. Fluids provide energy dissipation mechanism for these devices by developing resistive forces under the apllication of a strong magnetic or electirc field. As a result, the degree of polarization of the fluid the energy dissipation capacity can be changed by adjusting the power supply that controls these field, [1]. In case of loss of power supply, shock absorbers act as magnetoreological dampers thereby maintaining a degree of protection of the structure [2]. Unlike the other systems who consists of an variable orifice opening which are limited depending on valve size, electro-magnetic fields used by these systems are activated within a few milli-seconds, [1].

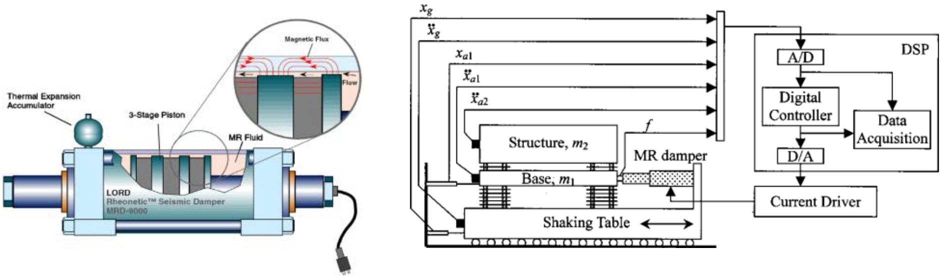

Fig. 9 – Magnetoreological damper [5]

The dynamic characteristic of the system, based on histeretic curve Bouc-Wen, (fig. 10) are presented in (eq.3):

(3) $$F = c_o \cdot \dot{x} + \alpha \cdot z$$

F-force generated by the damper

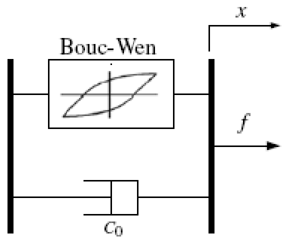

Fig. 10 – The histeretic curve Bouc-Wen of magnetoreological damper [5]

3.3.2 Semi-active stiffness dampers

The semi-active stiffness dampers consists of s cylinder filled with a fluid, a piston and a valve controlled by an motor which adjust the valve opening, thereby controlling the flow of the viscous fluid (most commonly used is oil). This system adds stiffness to the system when the valve is closed and dissipate energy when the valve is open, all of that are made by using a suitable control algorithm, [2].

3.3.3 Semi-active tuned liquid dampers

Seismic isolation system with tuned liquid dampers was introduced by Sakai et al, beeing an other type of passive damping system, where the solid mass is replaced by a liquid (usually water), (fig. 11).

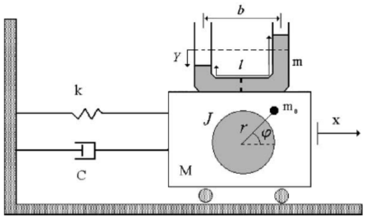

Fig. 11 – Schematical model of a tuned liquid damper

It is considered a U-shape container in which the movement of the fluid through a hole from one column to another develop control forces, which counteracts the seismic forces acting on the structure. In a passive tuned liquid damper the orifice size is fixed, but in a semi-active tuned liquid damper the hole size is variable thus can control the displacement of the structure, [2].

3.3.4 Semi-active tuned mass dampers

A semi-active tuned mass damper consists of an added mass, a spring and damping elements, thus the vibrations can be transferred to the tuned mass damper and dissipated by the damping mechanism of the system. The traditional system of tuned mass damper is based on a linear model that is very well defined, but the non-linear model of energy dissipation can lead to better performance of structural control, but is still in research.

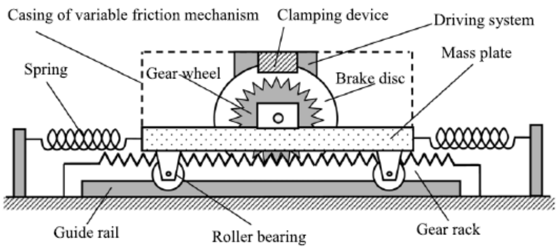

Fig. 12 – Mechanical model of a friction tuned mass damper

An example of a nonlinear model of the tuned mass damper is the friction type, (fig. 12). Compared with classical one, the friction system shown in fig.16 has the following advantages: energy dissipation due to friction can be achieved withouth the need of other dissipation devices, and the space needed for the installation of this devices can be greatly reduced. Semi-active tuned mass damper is activated only when the friction force that develops due to seismic movement inside the system exceedes the maximum sliding force. But this system can be blocked due to excessive friction forces loosing the capacity to dissipate energy. One way to overcome this disatvantage is to reduce the maximum sliding force, but in this case they may not be enough power to dissipate the energy, therefore determining the maximum sliding force is a very dificult problem. Another problem with this system is the detuning effect when the frequency does not reaches at the desired value, but using a multiple semi-active tuned mass damper , this can be solved, [7].

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Poly(ethylene-co-tetrafluoroethylene)-based permanent motorway roofs equipped with night lighting sources and thin film solar cells

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Abstract

This article presents the idea of providing newly-built motorways with permanent transparent roofs equipped with light sources and thin film photovoltaic solar cells, as a way to significantly improve road safety (by eliminating most of the problems associated with adherence changes on non-dry pavements and with reduced visibility), to improve road transport efficiency during natural precipitation periods, to drastically reduce road maintenance costs associated with snow removal and road infrastructure damage due to water, and also as a way to generate electrical energy. I show that poly(ethylene-co-tetrafluoroethylene) could be successfully used as the main constructive material for permanent motorway roofs, with part of the surface equipped with thin film solar cells. For Romania, assuming a 5000-km motorway network covered with ETFE roofs equipped with 20% peak efficiency photovoltaic cells on 60% of the roof surface and considering a yield correction factor of 0.8 (due to the constrained orientation of the roof), more than one third of the electrical power currently consumed in this country could be produced by this system.

Rezumat

Acest articol prezintă ideea dotării autostrăzilor nou-construite cu acoperişuri permanente transparente echipate cu surse de iluminat şi celule solare cu film subţire, ca un mod de a îmbunătăţi semnificativ siguranţa rutieră (eliminând cele mai multe probleme asociate cu schimbările de aderenţă pe carosabilul non-uscat şi cu vizibilitatea redusă), de a îmbunătăţi eficienţa activităţii de transport rutier în timpul perioadelor cu precipitaţii, de a reduce semnificativ costurile de întreţinere a infrastructurii rutiere asociate cu deszăpezirea şi degradarea infrastructurii datorită apei, şi de asemenea ca un mod de a genera energie electrică. Se arată că poli(etilen-co-tetrafluoroetilena) ar putea fi utilizată cu succes ca principal material constructiv pentru acoperişuri permanente pentru autostrăzi, cu o parte din suprafaţă echipată cu celule solare cu film subţire. Pentru România, presupunând o reţea de autostrăzi de 5000 de kilometri dotată cu acoperişuri din ETFE echipate cu celule fotovoltaice de eficienţă maximă de 20% dispuse pe 60% din suprafaţa acoperişului şi considerând un factor de corecţie al randamentului de 0,8 (datorită orientării constrânse a acoperişului), mai mult de o treime din puterea electrică consumată în prezent de întreaga ţară ar putea fi produsă prin acest sistem.

Keywords: Motorways, ETFE, road safety, road visibility, unfavorable meteorological conditions, wet pavement, snow removal, road accidents, thin film solar cells, photovoltaics.

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1. Introduction

Not much has changed in the last century regarding road construction paradigms. In essence, the motorways we built today are strikingly similar to the Autobahns of the early twentieth century, save for some environment-related aspects and some minor improvements in the design parameters. If anything, in the European Union and northern America, the cost and the duration of preparing and implementing motorway projects has constantly risen during the last decades. Going further, we can state that, on a technical note, the constructive principles for roads have remained essentially the same since the Roman Empire. Nevertheless, road networks are being built, extended, upgraded in capacity or modernized at a rapid pace throughout the world. It is therefore natural to research ways to improve the existing functions of the roads or to envision additional innovative functions that the roads could play.

The permanent motorway covering solution proposed in this paper aims to simultaneously solve three issues: eliminate the problems associated with the presence of water on roadways, increase safety by illuminating motorways during night time and generate electrical energy.

Part 2 of this paper is an overview of the problems generated by the water presence on road carriageways and their associated costs. Part 3 presents the general concept of permanent motorway roofs, while part 4 analyzes a specific solution having at its center a fluoropolymer as the main constructive material. Part 5 explores the energy generation function of the motorway roofs by photovoltaics. Part 6 integrates the ideas presented in the previous sections from the point of view of the research and development needed to bring the idea presented in this paper to practice.

2. The cost of water presence on road surfaces

The presence of water on roads, in one form or another, correlates with important costs associated with the road transport activity. We can arbitrarily classify these in the following three categories:

- costs of road accidents where non-dry pavement[2] plays a significant role;
- costs of delay, congestion – in general, the reduction of efficiency of the road transportation act;
- costs related to ice prevention and snow removal.

2.1. Road accidents associated with non-dry pavements

Every year road accidents are causing around 1.3 million deaths and between 20 and 50 million injuries worldwide, and the economic losses incurred by the victims, their families and the society as a whole translate, for most countries, to values of 1 – 3% of the GNP [19].

It is difficult to quantify how much of this cost can be attributed to non-dry pavements. Despite the fact that the theoretical mechanisms that describe the interaction between the user / vehicle and the non-dry road surface / environment are relatively well-known, there is rather limited knowledge regarding the quantification of accident risk increase caused by non-dry pavements (related to the condition of the pavement itself but also to the visibility issues associated with natural precipitation). Various empirical research has attempted to quantify the connection between water on roads and accident risk increase; for instance, a study [8] postulates that collision risk increases

[2] The phrase "non-dry pavement" was chosen to represent all situations where water is present, in various forms, on the road surface (roads covered with moisture, water, snow, ice, glazed frost and any combinations of these).

by 50 – 100% during natural precipitation. The same study estimates that in Canada 7% of injury road accidents and 12% of property damage road accidents are directly attributable to unfavorable weather conditions, and that these accidents cost the country 1,1 billion C$, out of which about 700 million C$ are medical costs and the rest property damage costs.

In Romania, „*neadaptarea vitezei la condiţiile de drum*" („not adjusting the speed to the conditions of the road") is currently the main cause of road accidents. For instance, in the first four months of 2011, this factor was the main cause for 26% of the road accidents in Cluj county [7].

2.2. The economic impact (other than accident-related) of non-dry pavement on road transport

Unfavorable weather is responsible for other economic costs, borne by the direct and indirect beneficiaries of road transport, mainly associated with the increased duration of the road transportation act. The results of a 2007 study regarding the reduction of the speed on USA freeways in free-flow traffic conditions due to inclement weather are shown below.

Table 1. Reduction of mean speed due to natural precipitation (freeway, free-flow traffic) [12]

Precipitation type	Reduction at onset of the precipitation	Maximum reduction (recorded precipitation intensity)
Rain	2.3%	4.8% (1.5 cm/h)
Snow	6%	20% (0.3 cm/h)
Freezing rain (*Baltimore*)	14%	27% (0.53 cm/h)
Freezing rain (*Seattle*)	31%	

It is likely that during inferior conditions (lower class roads, lower service levels) the reduction in speed is higher. One can estimate that in Romania the duration of interurban travel on the national road network increases during winter, overall, by 10-15%[3].

2.3. Costs related to ice prevention and snow removal

Winter road maintenance activities (mainly preventing or removing solid water from the roadway) are expensive. A 1998 study [18] estimated the total yearly direct expense with snow removal in the US to be approximately 2.1 billion dollars. Obviously, the expense today is significantly higher, since only during the last four years the price of sodium chloride (the main chemical used in snow removal and ice prevention) has doubled in some cases [15]. In Ontario, Canada, half of the highway maintenance budget is spent on winter maintenance operations, specifically on snow and ice control [10].

Furthermore, indirect costs associated with ice prevention and snow removal (such as the impact on the environment, the damage to the cars and roads etc.) are estimated to be several times higher than the direct costs [6].

3. Permanent road roofs – form and function

3.1. General presentation of the concept

[3] This estimate is based on the author's personal experience and on discussions with frequent users of the national road network.

This paper explores the possibility of equipping high-speed roads (motorways, expressways) with permanent transparent roofs, to completely eliminate the presence of the water from the carriageway. Figure 1 is a schematic drawing of the proposed solution for a motorway following the Trans-European Motorway standards [20].

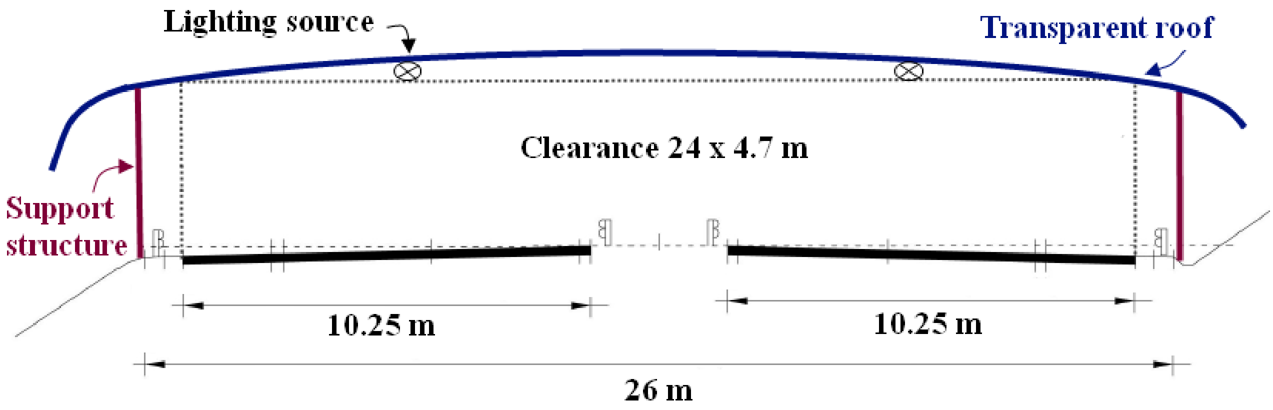

Figure 1. The author's vision regarding permanent covers for motorways

Considering a four lane motorway, the minimum transversal clearance that must be provided by the roof and its structure is 24 m x 4.7 m. The geometry of the roof must ensure proper drainage and must provide maximum protection against the combined effect of high lateral winds and precipitations (e.g. blizzards).

3.2. Additional functions

a). Lighting

A 2009 study [21] has shown that the night lighting of extraurban roads in Holland has a significant effect on road safety and is correlated with a 54% reduction of road accidents with deaths and injuries. It is therefore easy to imagine the addition, on the roof supporting structure, of light sources as shown in Figure 1. The height of the structure imposes the usage of distinct lighting for each carriageway, and also increases the density of the light sources because of the reduced useful luminance cones. Paragraph 4.10.3.6.3 of the TEM standards [20] recommends that the installation height be at least half of the width of the unidirectional carriageway when using bilateral lighting. The solution proposed in Figure 1 practically obeys this, since the installation height will be about 4.7 m while the width of one carriageway is 10.25 m.

b). Electrical energy production

Should this solution be implemented on a large scale, the road roof will end up covering a significant area. For instance, considering 1000 kilometers of motorway, the area of the roof will be more than 2.5×10^7 m, or 2500 hectares. It is therefore only logical to consider functionalizing this „already used” surface with devices converting the sun's radiant energy into electrical energy. Equipping the roof with photovoltaic cells will be therefore explored in section 5 of this paper.

3.3. Defining a set of properties for the motorway roof

Before investigating possible practical solutions, one must define a set of properties that any solution considered must fulfill. Table 2 presents in a descriptive manner such a set of properties, which was built starting from the properties that civil structure roofs must fulfill [13], considering the particular characteristics required for the application discussed herein. The table also presents the relative importance of the various properties (1 = mandatory, 2 = important).

Table 2. The most important properties that a material must fulfill in order to be used as the main constructive material for permanent motorway roofs

Type of property	Description of the property	Relative importance
Structural and resistance	As light as possible	1
	Supports loads from wind and snow	1
	Works in the atmospheric temperature interval	1
	Resistant to deformations in the support structure	1
	Resistant to hail	1
	Resistant to other forms of mechanical aggression (e.g. the claws and beaks of birds)	1
Optical	Transparent to visible light	1
	Reduction of sun glare	2
Fire safety	Incombustible or at least prevents fire propagation	1
Acoustic	Acoustically transparent	2
Durability	Unaffected by UV radiation	2
	Unaffected by chemicals presented in the atmosphere	2
	Anti-adhesive (prevents buildup of bird excrements, dust etc.)	2
Environmentally friendly	Low production energy	2
	Recyclable	2

Although the author has briefly investigated various potential materials, this article will present the poly(ethylene-co-tetrafluoroethylene) as the proposed constructive material for permanent road roofs.

4. Poly(ethylene-co-tetrafluoroethylene) as the constructive material for motorway roofs

4.1. Poly(ethylene-co-tetrafluoroethylene)'s usage as a roofing material

Poly(ethylene-co-tetrafluoroethylene), abbreviated ETFE, is the copolymer of ethylene C_2H_4 and tetrafluoroethylene C_2F_4. Discovered in 1972, it is part of the fluoropolymer family – plastic materials with widespread uses. ETFE can be easily synthesized for instance starting from fluorine, methane and ethylene [11], as shown in the following sequence:

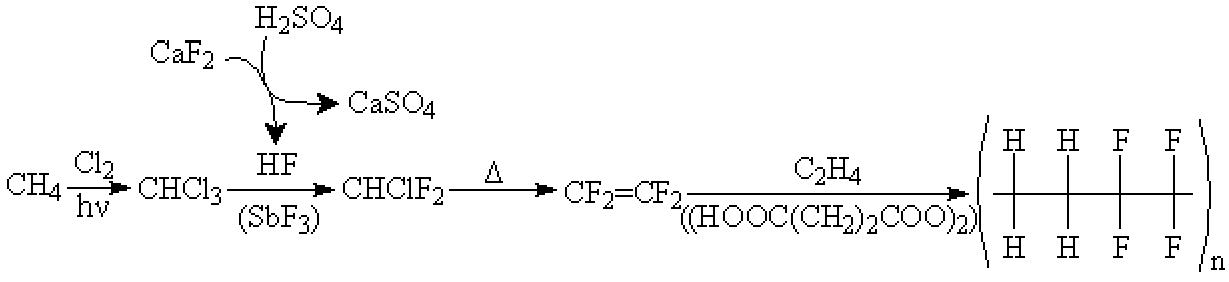

Figure 2. An industrial synthesis of ETFE

The addition of a third monomer (typically a higher polyfluoroalkene) in small quantities is used to improve the mechanical properties (for instance the elastic modulus [9]). Due to its specific set of properties, ETFE is used for a variety of applications, under trade names such as Texlon® (by Vector Foiltec), Tefzel® (by Du Pont) or Fluon® (Asahi Glass Company). In particular, ETFE has been used during the last decades as the main constructive material for roofs, its main advantage over the traditional glass solution being its reduced weight, which translates into significantly lighter roof support structures. Figures 3 – 5 show three buildings equipped with ETFE roofs.

Figure 3. The Beijing National Aquatics Center (2008)

Figure 4. School in Lancashire, Great Britain (2008)

Figure 5. Allianz Arena, Munich (2005)

4.2. Brief description of the properties of ETFE

a). Structural and resistance properties [16]

ETFE is used for roof construction under the form of *ETFE cushions*. A cushion is made from 2 – 5 ETFE films, each having a width of 100 – 200 µm, sealed along their perimeter. A rectangular cushion's maximum size is 3,5 x ∞ m. By filling the space between the films with air (cca. 200 – 800 Pa above the atmospheric pressure) *pneumatic prestressing* is achieved, allowing the cushions to carry significant loads – they can typically withstand wind loads of 200 kg/m^2 and snow loads of 300 kg/m^2 (although much higher values, e.g. 3000 kg/m^2 for snow, are mentioned in the literature [14]).

However, since the weight of the ETFE film is 175 – 350 g/m^2, the weight of ETFE cushions is only 2 – 3 kg/m^2. Therefore, for the same covered surface, this material is approximately ten times lighter than traditional glass – which enormously reduces the requirements for the roof supporting structure. As an elastic material, ETFE can extend to up to 400% of its length along one dimension and still remain in the elastic domain. This is extremely important, since the material need not be isolated from the potential deflections in the support structure – which itself need not be rigid.

An air pumping system continuously maintains the pressure inside the ETFE cushions; since the air is not circulated, the energy consumption associated with maintaining the pressure is low. The system can be equipped with sensors which in the case of heavy winds and snowfalls will automatically adjust the pressure to successfully withstand the additional loads. For example, the ETFE envelope of the Allianz Arena in Munich is equipped with 12 sensors that will adjust the pressure to withstand loads corresponding to 1.6 m of snow [2]. ETFE shows optimal behavior at atmospheric temperatures, although it shows some loss of strength at temperatures above 70^{o}C [14]. The major mechanical disadvantage of the ETFE film is its reduced resistance to pinching, which can be a problem due to the presence of birds (beak pinching). Nevertheless, punctures created by pinching do not propagate and only affect the superior ETFE film in a cushion. Certain ETFE solution integrators equip the structure with discrete nylon-covered steel cable networks (bird wire deterrents) which preven birds from reaching the ETFE film [4].

b). Fire safety and resistance

ETFE has low flammability (270 ^{o}C). At temperatures above 200 ^{o}C, the ETFE film will soften and eventually break to allow combustion gases to escape in the atmosphere [1]. ETFE is self-extinguishing, and the material will not generate falling pieces of molten material.

c). Optical and acoustic properties

ETFE transmits between 94% and 97% of the light from the visible spectrum [16]. However, the film can be modified by printing to eliminate the sun glare effect without affecting transparency.
ETFE is an acoustically transparent material, having a weighted sound reduction index of R_w = 8 dB (for comparison, a dual layer glass window has R_w = 42 dB) [16]. While this is generally a disadvantage for using ETFE as a replacement for glass in civil constructions, in the case of its utilization as a material for motorway roofs this would be an advantage, since it would prevent a reverberation effect (similar to the one encountered in tunnels).

d). Durability and environmental protection

Since it is formed from saturated organic macromolecules without reactive functional groups, ETFE is chemically inert, unaffected by compounds and pollutants present in the atmosphere or by UV radiation. ETFE roofs in buildings that have been around for more than 30 years prove that the material did not suffer any significant degradation in form or function [14].
Because of the very smooth texture of the ETFE film, the material has strong anti-adhesive properties, and natural precipitation will easily remove any materials deposited on its surface. This increases the duration of a cleaning cycle 5 – 10 times in comparison with glass [1]. Hence, an ETFE roof normally only needs cleaning once every five years for its external surface and once every ten years for its internal surface.
The material is entirely recyclable and the energy consumption needed for its production is lower compared to alternative materials. In conclusion, ETFE successfully fulfills all the conditions associated to the properties presented in section 3.3.

5. Thin-film silicon photovoltaic cells on ETFE motorway roofs

5.1. Overview of the current state of photovoltaic-based electricity generation technologies

The photovoltaic (PV) effect (the generation of voltage and electrical current in semiconductors upon exposure to light) is the core process for generating electricity by using the sunlight, one of the most promising alternatives for solving this planet's energy issue. Consequently, there is significant related ongoing research, mainly centered around the objectives of increasing the efficiency and reliability as well as decreasing the cost of existing PV cell types, but also finding new semiconducting chemical compounds or mixtures.

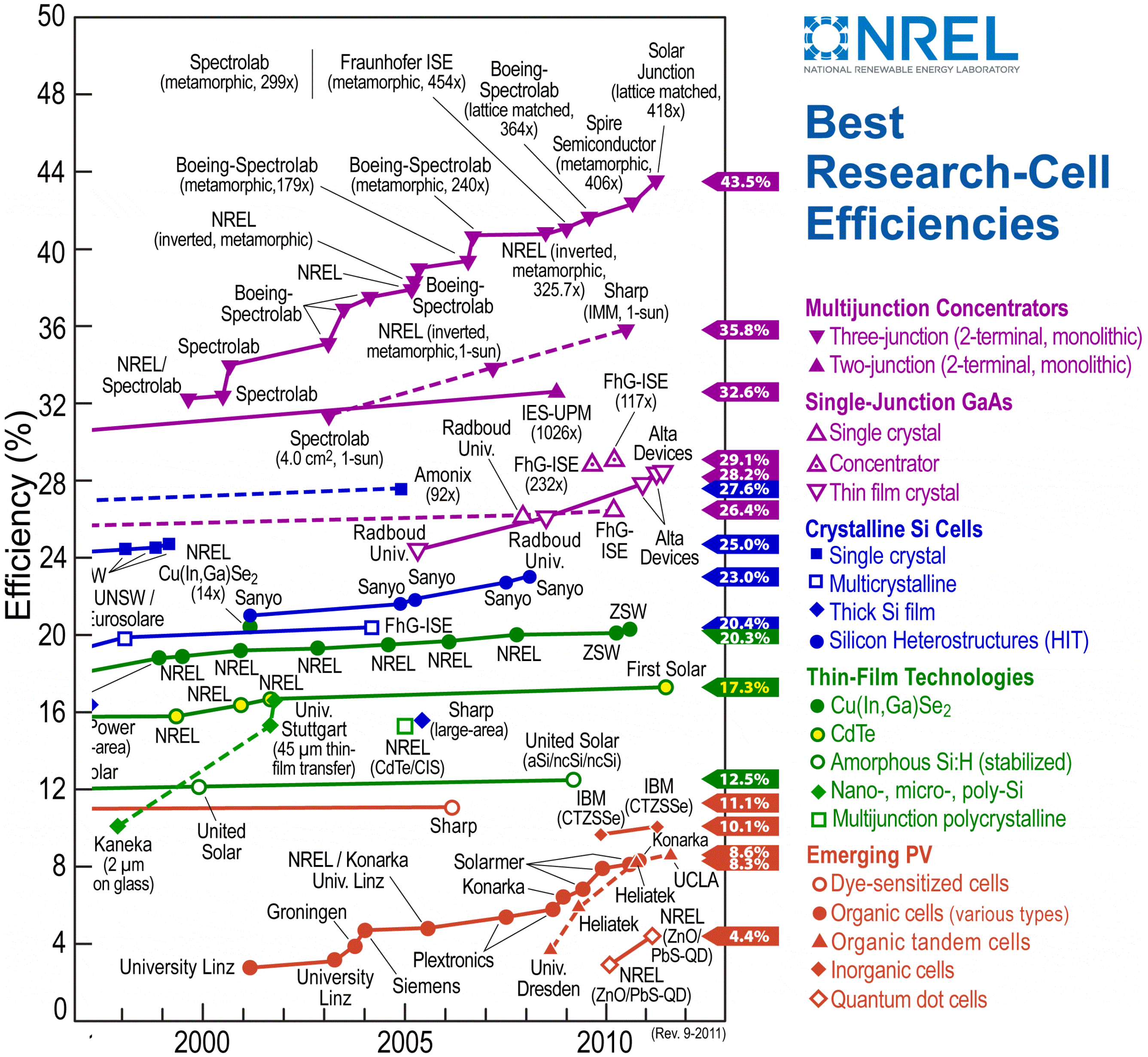

Figure 6. Various PV cells and their efficiency
(National Renewable Energy Laboratory of the United States of America[4])

Silicon-based cells have been studied most extensively, following by cells based mainly on elements from groups 13 and 15 of the periodic table. Constructive solutions with more than one p-n junction have allowed for a more efficient use of the light spectrum, and in combination with the concentration of light have lead to the currently highest light conversion efficiencies. Relatively in its infancy is the exploration of using as semiconductors organic compounds, either individually (conjugated organic compounds, where the band gap is between the HOMO and LUMO orbitals of the delocalized system) or in electron donor-acceptor pairs. However, there are still important problems to be solved before organic-based PV's will be truly viable outside the lab.

From a practical perspective, we can also classify PV cells into *rigid* (based on bulk crystalline layers of semiconducting materials) and *flexible* (based on thin films of semiconducting materials

[4] The original image was edited for better page fit.

deposited on flexible substrates). Despite their lower efficiency compared to their "traditional" crystalline silicon counterparts, flexible thin film solar cells (FTFSC's) have advantages related to their reduced mass and their spatial flexibility.

Two major types of FTFSC's are worth considering in the context of this paper: amorphous silicon based (a-Si) and the ones based on the mixed diselenide $CuIn_xGa_{(1-x)}Se_2$ (CIGS)[5]. Commercial products exist with typical peak efficiencies of 8% (for a-Si) and 12% (for CIGS) that resemble "carpets" that are easily installed on existing structures such as roofs.

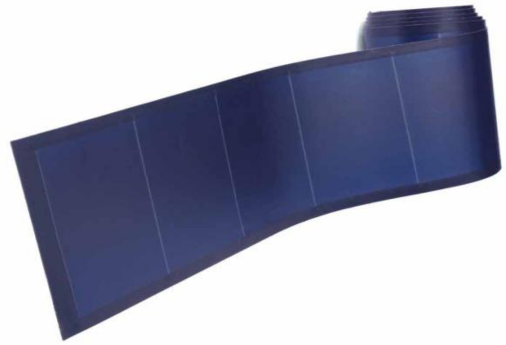

Figure 7. Example of FTFSC-based product: The Unisolar PVL-68 laminate.
Maximum power 68W; dimensions 2771 x 373 x 21 mm; weight 3.9 kg [20]

The current economic downturn coupled with increasing inventories has lead to a significant decrease of the market price of FTFSC's.

5.2. Motorway roofs and solar energy – a scenario for Romania

Building roofs for motorways as proposed in this paper would generate a significant roofing area. Assuming a roof width of 27 m, for 1000 kilometers of motorway this would equate to an area of 2700 hectares. What if we could make use of this area by incorporating thin film solar cells in the roof?

Currently Romania has an ambitious motorway construction plan. One of the most important aims is to complete a west – east motorway between the Romanian-Hungarian border and the Black Sea, following the route Nădlac – Sibiu – Bucharest – Constanța. The approximate length of this motorway will be 885 kilometers, and more than half of it is either open to traffic or under construction. The corresponding roof area would thus be 2.39×10^7 m^2.

Since a key feature of the roof would be to allow for a significant amount of natural light to serve the motorway, we must assume that we would cover only a fraction (say 60%) of the roof with the opaque FTFSC's (CIGS or a-Si deposited on ETFE), leaving the rest as transparent (alternatively translucent) basic ETFE cover. In practice, this could be accomplished by alternating transversal stripes of FTFSC-ETFE and ETFE with widths chosen such as to ensure a comfortable "continuity" of natural lighting for drivers[6].

[5] For the sake of completeness, two other classes are worth mentioning: on one hand, the CdTe-based cells that are cheaper than both CIGS and a-Si and more efficient than a-Si but, from the author's point of view, don't have a sustainable future (especially due to the rareness of Te and the toxicity of Cd) and on the other hand the organic-based cells that are not yet practical enough.

[7] Alternatively, other geometrical arrangements can be envisioned: chessboard, honeycomb etc.

Assuming cells with a 12.5% efficiency (which would therefore generate a peak energy of 125 W_p/m^2), and introducing a yield reduction factor of 0.8 (associated with the constrained orientation of the cells as dictated by the roof geometry), the total peak energy generated by the roof of the 885-km motorway would be:

$$2.39 \times 10^7 \text{ m}^2 \times 125 \text{ W/m}^2 \times 0.6 \times 0.8 = 1.43 \text{ x } 10^9 \text{ W, or } 1.43 \text{ GW.}$$

The following figure presents the total electrical energy production (split by source) and consumption of Romania for the week 1 – 7 November 2011.

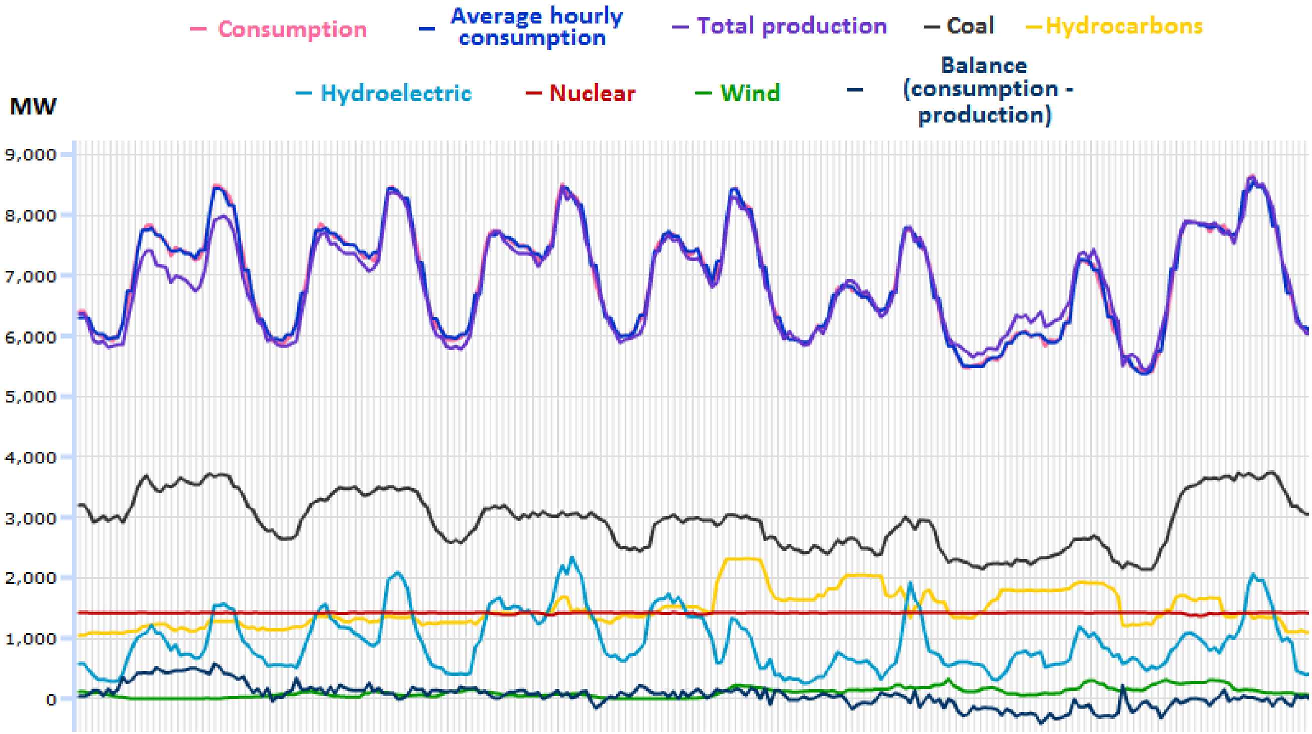

Figure 8. Total electrical energy production and consumption in Romania for the week 1 – 7 November 2011
(Source: Transelectrica SA. Real time data can be obtained at http://www.transelectrica.ro/openflash/grafic.php?ofc=date.php)

One can see that on average energy production (and consumption) in Romania varies between the two daily extremes of about 6 GW (at about 3 AM) and 8.5 GW (at about 7 PM[7]). In conclusion, installing an FTFSC-ETFE roof based on currently commercially available technologies only for the motorway Nădlac – Constanța would ensure, during peak solar radiation periods, about 20% of the electrical energy consumed by the country!

Assuming a daily power production rate equivalent to four hours of peak efficiency, for one year this system would generate:

$$1.43 \text{ GW} \times 4 \text{ hours/day} \times 365 \text{ days/year} = 2087.8 \text{ GWh/year.}$$

Since the annual electric energy consumption for Romania is (2008 estimate) 50590 GWh/year [3], the system would therefore generate 4.13% of the country's power.

Optimistic scenario

[7] Notice the reduced weekend peak values of less than 8 GW for Saturday, November 5, 2011 and less than 7.5 GW for Sunday, November 6, 2011.

Assuming that in the near future FTFSC's will reach a 20% peak efficiency in real-life settings (already available in laboratory conditions), and assuming the development of a 5000-km motorway network in Romania, the solar energy generated from motorway roofs would thus be:

$20/12.5 \times 5000/885 \times 4.13\% = 37.33\%$ of the total current electric energy expenditure.

Considering peak values, the system would generate

$$20/12.5 \times 5000/885 \times 1.43 \text{ GW} = 12.93 \text{ GW}$$

This is approximately 170% of the total national electrical energy consumption during the hours of maximum solar radiation[8]!

In conjunction with the expected commissioning of reactors 3 and 4 of the Cernavodă nuclear power plant (which would provide an additional 1.4 GW), this would allow Romania to essentially reach a goal of 100% non-carbon electrical energy generation, i.e. renewable and nuclear sources only. Of course, taking into account load-balancing needs, the country would need to invest in pumped-storage hydroelectric power plants. In this respect, it is worth mentioning that the government is in an advanced stage regarding the preparation of the construction of such a plant in Tarniţa (Cluj county), planned to have a 1 GW capacity [17].

6. Conclusions

The theoretical analysis presented in this paper leads to the conclusion that equipping motorways with permanent roofs that would generate electricity through the photovoltaic effect could be feasible not only economically but also financially. There are two reasons why this happens:

a). Economies of scope. Since this is an integrated solution the overall implementation costs will be lower than individual costs. For instance, there will be only one support structure for the motorway roof, the motorway lighting sources, the PV cells and the electric power transmission lines; the cost of labor and installation will also be reduced etc.

b). Economies of scale. Unlike roofing or PV cells installation projects for civil buildings, in this case there will a relatively standard and simple design that will be repeated on a large scale.

In order to proceed with this idea, the following issues must be approached:

1. Devising technical solutions to address special situations (e.g. very long and / or high bridges and viaducts, points where the motorway is overpassed by other infrastructure), both from the point of view of construction and maintenance.

2. Creating a standard design for the motorway roof equipped with night lighting and FTFSC's and estimating its costs.

3. Conducting a detailed cost-benefit analysis which would take into account all the benefits brought by this solution (although some of them are hard to quantify, as shown in section 2.1) weighted against the cost of the solution.

4. Implementing the solution on a pilot motorway segment (either existing or in construction – the latter would be probably easier). Of course, political (and also media and civic) support for this initiative would be needed – however, marketing the idea should not be difficult for obvious reasons.

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[8] One should notice that eliminating one of the optimistic scenario assumptions (the increase in the peak efficiency from 12.5% to 20%) leads to a theoretical production level during peak radiation periods that is roughly equivalent to the country's electric energy consumption.

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Curves settlement in areas with large gradients and the danger of aquaplaning in these areas

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Abstract

The first part of this paper presents the spatial settlement of a lay-out. A description of the types of cross profiles seen on a road, both aligned and curved, is made. Then the settlement of an isolated curve is described, according to STAS 863-85. Successive curves are presented, both the same directions and the opposite directions curves, and an isolated curve settlement for highways according to PD 162-2002 it also presented. In all these cases it is shown how the water drains from the carriageway, and the dangers of this water flow for vehicles. There is always the risk of an accident due to aquaplaning. The present article enumerates the contributing factors to the occurrence of aquaplaning. Finally a case study is done on a curved road section in an area with declivity, compared with a plane area, showing the danger posed by aquaplaning for these areas.

Rezumat

Lucrarea prezintă în prima parte, modul de amenajare în spaţiu a unui traseu. Se face o descriere a tipurilor de profile tranversale întâlnite la un drum, atât în aliniament cât şi în curbă, apoi se prezintă modul de amenajare a unei curbe izolate conform STAS 863-85. Sunt prezentate amenajările curbelor succesive de acelaşi sens, cât și de sens contrar, precum şi amenajarea unei curbe izolate în cazul autostrăzilor conform PD 162-2002. La toate aceste cazuri este prezentat modul de scurgere a apelor de pe partea carosabilă, precum şi pericolul reprezentat de aceasta pentru autovehicule, existând oricând riscul producerii unui accident datorită acvaplanarii.În lucrare sunt prezentaţi factorii care contribuie la apariţia acvaplanarii. În final este făcut un studiu de caz, pe un sector de drum în curbă pe o zonă cu declivitate, în comparaţie cu o zonă în palier, arătând pericolul care îl reprezintă acvaplanarea pentru aceste zone.

Keywords: aquaplaning, curves settlement, camber, clothoid, road surface, water drainage, road design

1. Introduction

Design and construction of roads is a very important element and it presents special issues to other engineering works. In design and in execution one has to consider the establishment of systematic solutions for planning and road building in plan, in longitudinal and cross sections profiles, and to ensure adequate road structures to motor traffic, and also to ensure traffic safety. In this sense, the behavior of the rod during the rain, and to prevent the effect of aquaplaning, is one of the main priorities.

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2. Space arrangements for transversal profiles according to existing standards

Roads are continually subjected to the action of water from rain or from snow. Because of this water flow is a very important problem in road construction. To protect the embankment against the flow of water, a series of collecting and draining water devices to are being used. From the surface used devices we include: ditches, culverts, canals, fast waterfalls, and drains, used in particular to collect the groundwater.

For the draining of water from the carriageway the road is constructed using transverse profiles with a slope towards the side of the road, to the shoulders. The pathway form, or the camber, can be constructed in several ways[1]:
- Curved camber, used specifically for the lower class roads (Fig. 1, A)
- Two flat slopess camber, as a roof, specific for concrete road, cement roa in general (Fig. 1, B)
- Roofs connected in the central area form camber, specifically used for modern pavement, asphalt (Fig. 1, C)
- Eaves form camber, single plan slope, specific for the curve areas (Fig. 1, D)

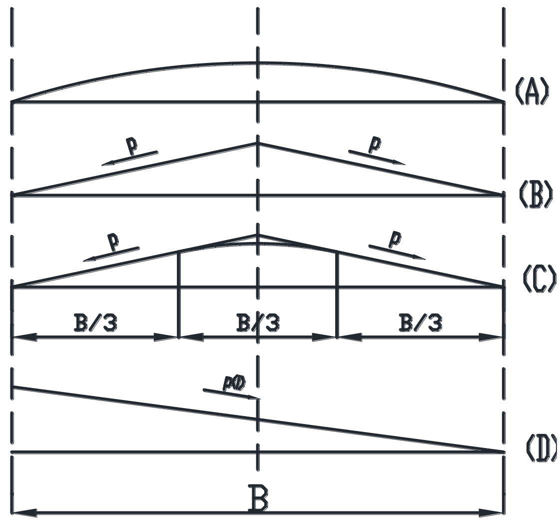

Figure 1. Types of camber

The slope for the cross section of modern pavement, according to STAS 863-85 is p= 2.5% outward. For a concrete pavement one can use a slope of 2%. Changing the shape of the transverse profile for the alignment curve is performed using two stages[2]:

1. Conversion – represents the settlement by rotating around an axis, usually the road shaft, until negative superelevation, from outside the curve, reaches the extension of the interior one, with the same slope "p". This arrangement starts at a distance l_{cs} before the curve. The over-widening is also made on the same distance.
2. The banking – represents the continuing pathway surface rotation around the axis road until it reaches the value "i", for the banking. The value "i" is found in STAS 863-85 and has values between 2.5 and 7%, depending on the curve radius and the design speed.

The banking and the conversion are designed to prevent vehicle skidding to the outside of the curve. Isolated curve settlement, for which the radius is less than the current radius, is made according to our STAS 863-85[3], by switching to a type roof profile to a converted profile, on a l_{CS} length to the entrance of the curve, then on the following clothoid the slope has a linear increase from p% to i%.

The slope will remain the same for the entire length of the central arc. A sketch of a design isolated curve using clothoid and central arch, according to STAS 863-85[3], is shown in Fig. 2.

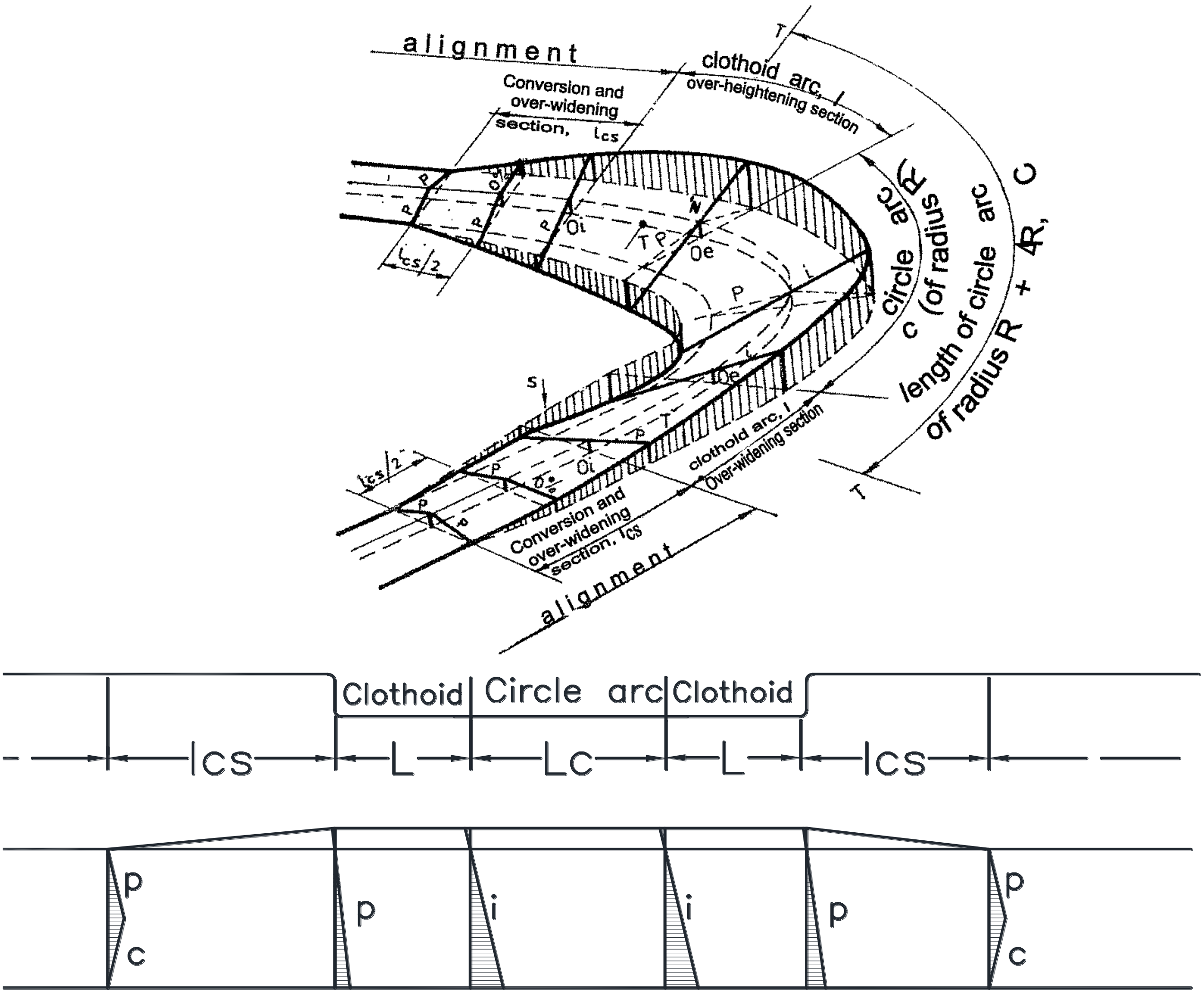

Figure 2. The design of an isolated curve using clothoid

If the intermediate alignment between two curves is smaller than 1.4 * V, where V = the design speed, then the two curves are considered consecutive. Successive curves can be of two ways[4], successive curves of the same direction or opposite direction successive curves. The design of successive curves of the same direction is shown in Fig. 3, and in Fig. 4 is presented the development of successive curves of opposite directions.

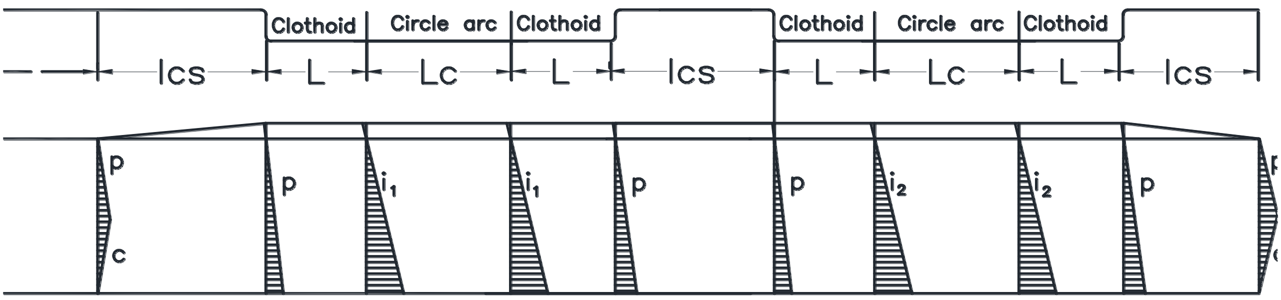

Figure 3. Design of the same direction successive curves

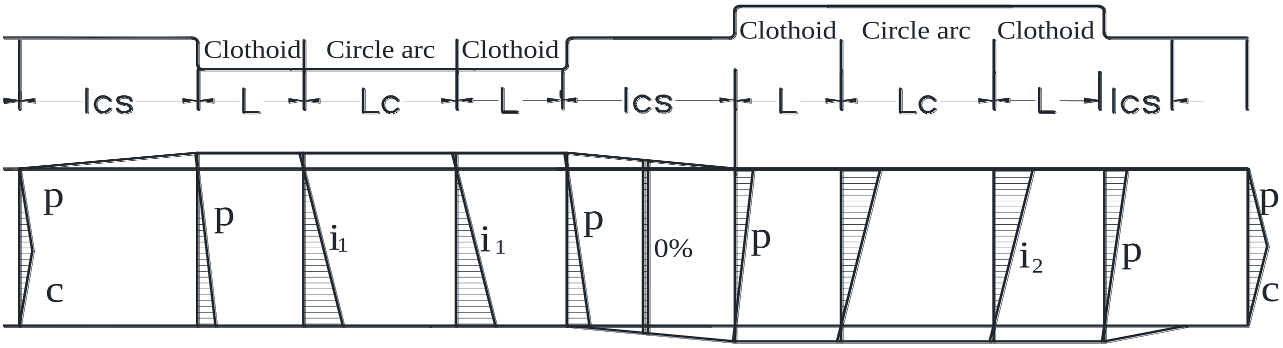

Figure 4. Design of opposite directions successive curves

In the case of highways we have two unidirectional ways and a central zone. The development of cross section curves, for each highway lane, is done separately for each band according to PD 162-2002[5]. An example of designing an isolated curve is shown in Fig. 5. The arrangement of successive curves is similarly as in the other categories of roads, both for the same direction and for opposite directions successive curves. The difference is that for the highways we do not have over-widening[6].

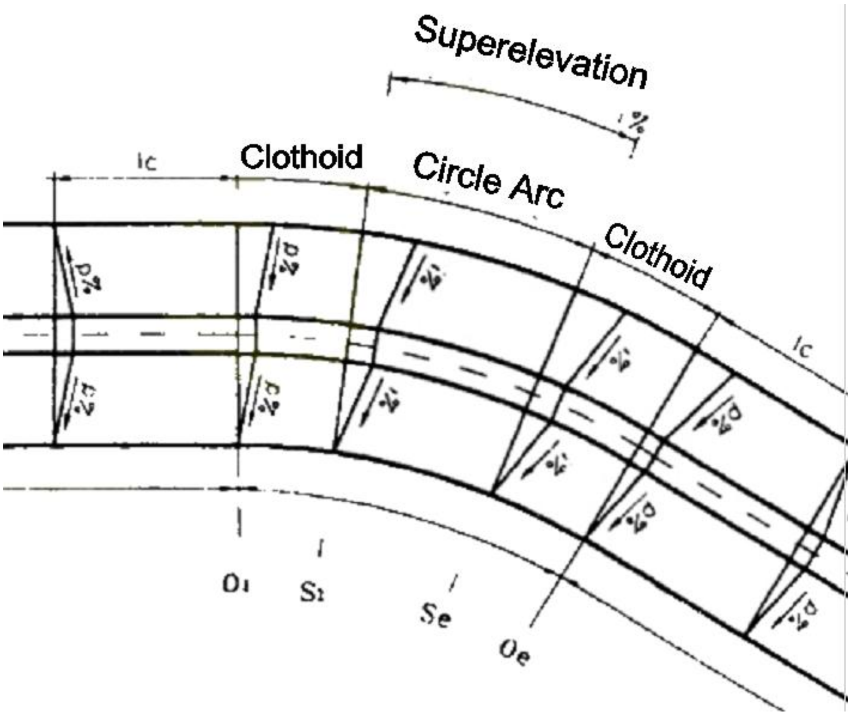

Figure 5. The development of highway curves, according to PD 162-2002[5]

3. Aquaplaning

For the draining of water from the carriageway, the road alignment is arranged in transverse profile with a slope towards the road, and for the curves the slope is towards the interior, as shown in the previous chapter. In the case of highways, in a curve we usually built a longitudinal and a sewer drain, on the road axis, to drain any water from the outside unidirectional band, without the water passing over the inner band.

The water drainage from the carriageway, as soon as possible, is especially important in order to prevent vehicles aquaplaning and thus avoid accidents. Aquaplaning is the phenomenon whereby the rubber loses contact with the road, moving only on the surface of water[7].

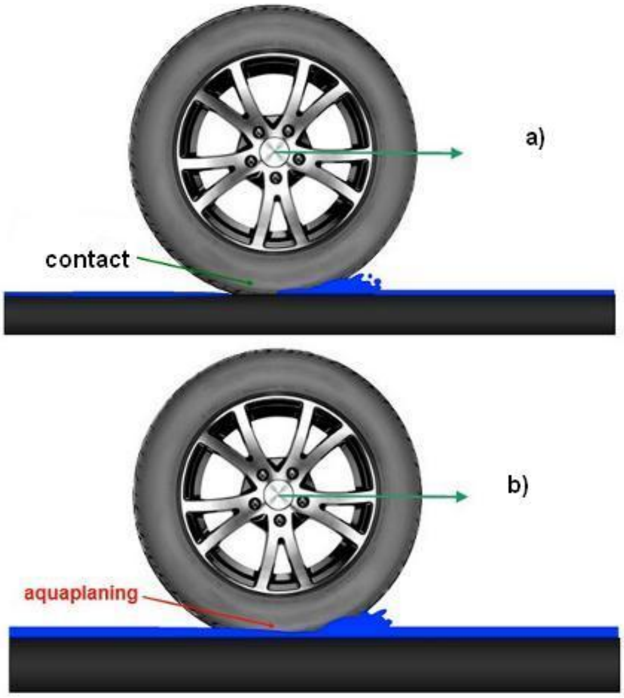

Figure 6 – The phenomenon of aquaplaning: a) partial, b) total [9]

Aquaplaning is also the main cause of accidents in time of rain. Aquaplaning depends on several factors. Among these we mention:
- Depth of water located on the road;
- Vehicles speed;
- Roughness of carriageway;
- Tire wear;
- The pressure of the vehicle on the road,

Aquaplaning is very dangerous because when the phenomenon is formed, the wheel will cease to have contact with the ground, losing control of the car.

Table 1 : Static friction coefficients for a concrete road

Vehicle speed (km/h)	Tire condition	Road condition			
		Dry	Wet	Rain (water<1cm)	Heavy rain (water<2cm)
Static friction coefficients					
50 km/h	new	0.85	0.65	0.55	0.5
	used*	1	0.5	0.4	0.25
90 km/h	new	0.8	0.6	0.3	0.05
	used*	0.95	0.2	0.1	0.05
130 km/h	new	0.75	0.4	0.2	0
	used*	0.9	0.2	0.1	0

* tire wear of 1.6mm, the lower limit legally allowed in Romania.

Aquaplaning occurs both when the wheel is rolling and when the wheel is locked. The liquid wedge creates on the tire a vertical force. For a certain speed V the liquid wedge deforms the tire, so a part of the tire rests on the liquid wedge causing the tire footprint on the road to decrease (Figure 6-a). If the speed increases the liquid wedge extends on the entire length of the contact surface (Figure 6-b).

Table 1 shows the static friction coefficients for a concrete road depending on road condition, vehicle speed and tire condition.

In order to calculate the vehicle speed at which aquaplaning will occur, we must take into account all the factors listed above. For this reason it is difficult to determine the exact speed, but empirical tests have shown that for a speed exceeding 72 km /h, a water film of 2.5 mm, and a length of at least 10 m, the aquaplaning phenomenon is formed[8].

4. The danger of aquaplaning in curves

The phenomenon of aquaplaning is extremely dangerous both in road alignment and in curves. For the alignment it is supposed that the vehicle speed and direction remain constant, and the risk of aquaplaning is lower. Even if it appears on some short areas, it is possible that the phenomena is not felt by the driver. For the road alignment the danger appears when the driver makes an overtaking, in the case of trajectory modification of a car, or when an obstacle appears, that requires braking or sudden detour. In Fig. 7 we have presented a water flow for a road with a cross slope of 2.5 percent, for a plane area and a slope area. Note that, in the drainage water landing is made approximately perpendicular to the axis of the road, and slope area, as the result of two slopes, transversal and longitude. Note that you route the water through the road surface is larger in area slope, favoring aquaplaning.

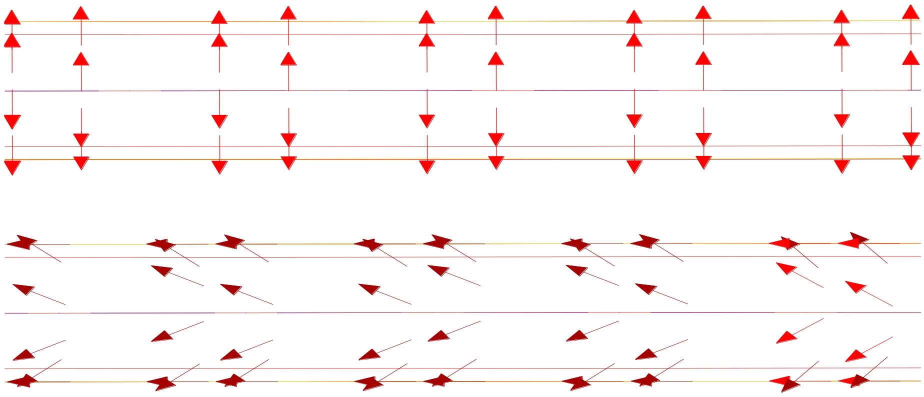

Figure 7. Water flow for a road alignment, on a plane area and a slope area

In the case of curves the situation changes because we have only one slope, to the inside curve, and since the beginning the danger of aquaplaning is greater, because the surface from which the storm water must be discharged is greater. At the same time for curves we have centrifugal forces that pull the vehicle to the outside of the curve, decreasing the tire grip and increasing the risk of aquaplaning and , respectively, of an accident .

Storm water drainage on a curve section with conversion or banking, on a plane area, is shown in Fig. 8. The storm water drainage within the interior of the curve can be observed.

If the curve is located on a slope sector, the situation changes radically. The storm water from the entire surface of the road, including the shoulder outside, flows on the resultant direction of the two slopes. This causes the water on the road surface lo flow along the road, leading to the formation of a water film above the carriageway. This promotes aquaplaning and therefore accidents.

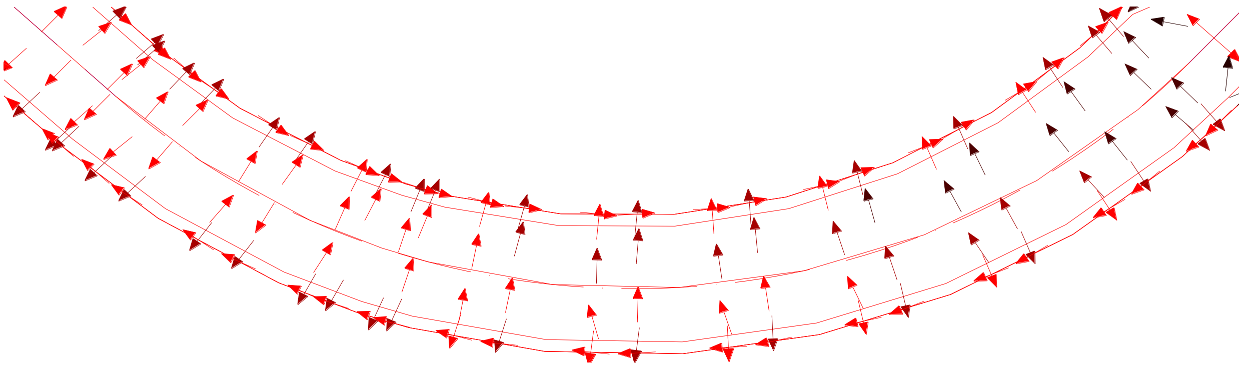

Figure 8. Water drainage on a curve section from a plane area

In Fig. 9 we have a water leak on sector in a curve with a radius of 60 m and a gradient in the longitudinal profile of about 6 %. Transversal profile slope is 7% according to STAS 863-85.
Note that in this case dangerous areas appear, prone to aquaplaning on the outside of the curve, where, because of combinations of slopes in longitudinal and tranversal profile, the meteoric water flows along the road, favoring aquaplaning. Areas prone to aquaplaning not only occur for small radius curves. In Fig. 10 we have represented the water drainage for a curve with a radius of 120 m, designed for a speed of 40 kmh, with a tranversal slope of 3.5%, according to STAS 863-85, and a longitudinal slope of 6.5 percent. We can see that here we have the same problems as for the previous curve, the direction of drainage on the road is almost parallel to the axis of the road.

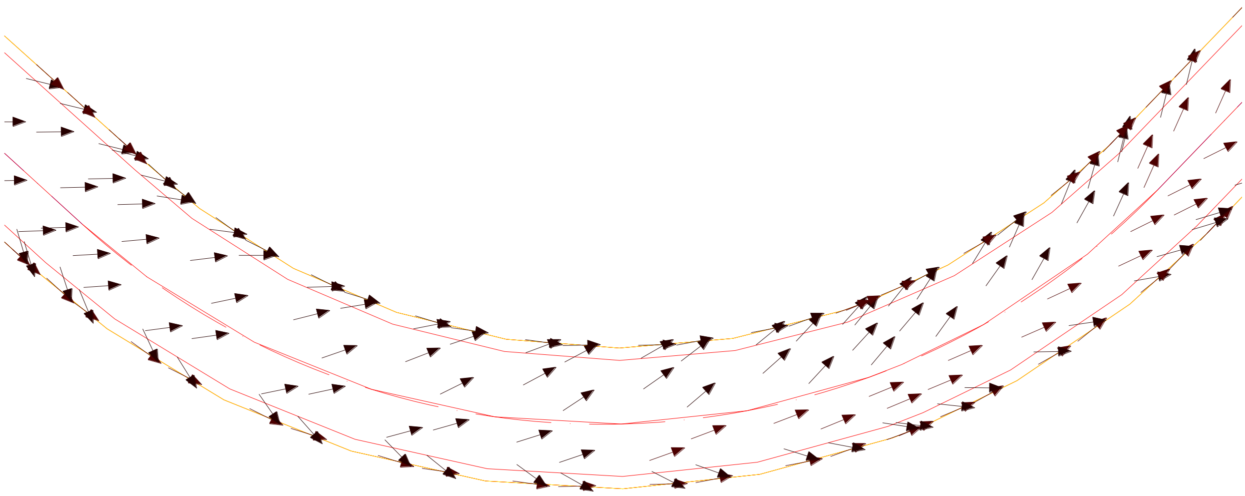

Figure 9 . Water drainage from the surface of a road for a curve with a radius of 60 m with a slope of 6 %

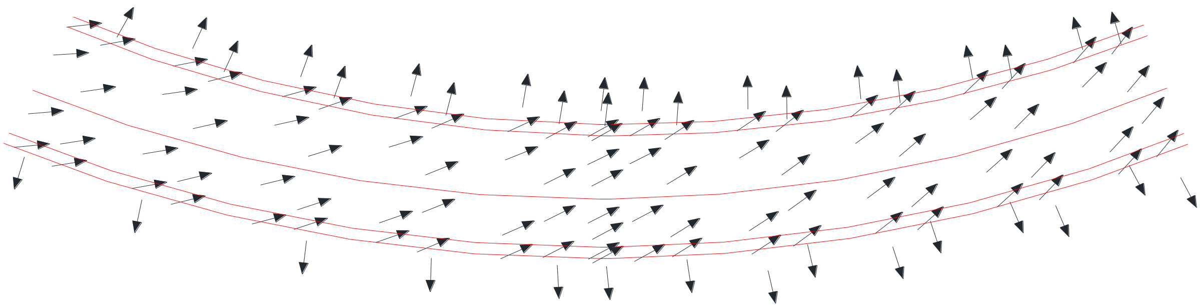

Figure 10 - Water drainage along the road for a curve with a radius of 120 m located on an area with a 6.5% slope

Water flow direction from the road and the draining speed varies, depending on angle between the alignments, design speed and the radius curve, elements that lead to the establishment of the transverse slope, and on the road declivity, element that sets the longitudinal slope. For this reason, the multitude of parameters on which it depends, is difficult to establish certain combinations of tranversal / longitudinal slopes, which are dangerous. Each case must be treated individually and checked the water flow, and in cases where there are problems, solve them by changing the curve elements, o by sizing of additional water collection devices.

The situation becomes more dangerous for the four lanes roads(Fig. 11), usually the vehicles travel on these roads at a higher speed, having a unique slope on all four lanes. In this case the road bands with a higher risk of aquaplaning are are the bands from the inside of the curve.

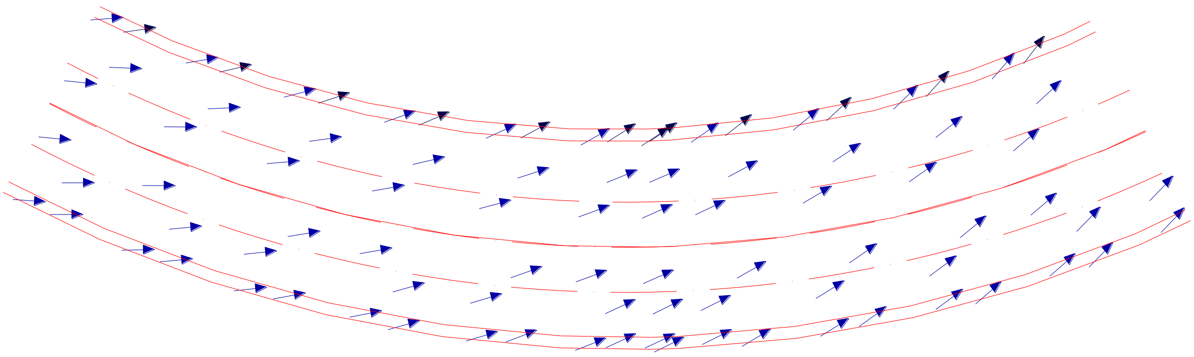

Figure 11 – Water drainage from the surface of a road with four lanes

Also a dangerous situation is the case of highways, where although in curves we have drains and a sewer system, in the longitudinal axis of the road, that takes the water from the outer lane. Here we have the largest amount of water on the road, on the band from the median area, which represents the higher speed lane. This can lead to accidents in wet weather with tragic consequences.

5. Conclusions

In road designing, both new roads and upgrading, or rehabilitation, in addition to the compliance with current regulations it is necessary to study the water flow on road surface. Because there are cases, where, dangerous areas can occur even if all the road elements have been designed according to regulations. These dangerous areas lead to the formation of aquaplaning phenomenon, being a major factor in accidents.

Acknowledgements
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The Asphalt in the RLPEP Project

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Abstract

The behaviour of the flexible road structures was and will always be influenced by their composition. The climatic conditions require certain characteristics for each of the components of asphalt mixture to be known in order to obtain efective pavements. In countries with high temperatures, such as Qatar, the proportioning is different from those in temperate climates. In this paper is presented a case study, the Ras Laffan Port Expansion Project (RLPEP), about the expansion of the Ras Laffan port from Qatar, in reference to the use of the bituminous mixtures in hot areas.

Rezumat

Comportarea structurilor rutiere suple a fost şi va fi întotdeauna influenţată de compoziţia mixturilor asfaltice. Condiţiile climaterice impun anumite caracteristici pentru fiecare dintre componentele mixturilor asfaltice, care trebuie cunoscute în vederea obţinerii unor îmbrăcăminţi eficiente. În ţările cu temperaturi ridicate, cum ar fi Qatar, dozajele sunt diferite de cele din zonele cu climă temperată. În lucrare este prezentat un studiu de caz, proiectul Ras Laffan Port Expansion Project (RLPEP), extinderea portului Ras Laffan din Qatar, cu referire la utilizarea asfaltului în zone calde.

Keywords: high temperatures, asphaltic mixtures, characteristics, tests

1. General data about RLPEP

The Ras Laffan Port Expansion Project represents the expansion of the existent harbor from the city of Ras Laffan, the industrial area (Ras Laffan Industrial City - RLIC) in Qatar.
The project is completed by CCG/TCC-JV (Consolidated Contractors Group/Teyseer Contracting Company-Joint Venture), a company specialized in engineering, procurement, installation and commissioning.

The beneficiary and, in the same time, the supervisor of this project is QP Qatar Petroleum.
The RLPEP project represents the study case for hot areas, considering its location in the State of Qatar, a hot area.
The project consists of three sections:

- Infrastructure
- Building

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- Marine

The project includes seven areas: Southern Breakwater, Main Breakwater, Central Cargo auseway, Liquid product Causeway, Gate 1, Gate 2 and Tank Farm.
The entire asphalt quantity in this project is 543,467 tons for the Base Course, 105 mm thick and 94,906 tons for the Wearing Course, which is 40 mm thick.
The CCG/TCC-JV Company, in order to ensure the supply efficiency, provided an asphalt plant for this project. The plant is 25 km away from the site and the residential area.
The plant is fully computerized, with oil heating system, and a capacity of 200 t/hr. It also has two insulated tanks with a capacity of 200 tonnes.

Figure 1. Asphalt plant

Figure 2. Asphalt plant control room

In the same area, with the asphalt plant, there is also a specialized laboratory, which can perform all the required tests, in order to ensure the quality of aggregates, bitumen and asphaltic mixtures produced here comply with the rquirements of the job specifications.
All the tests performed in this laboratory are verified and suprevised by a third part, ACES (Arab Center for Engineering Studies), together with the contractor's CCG/TCC-JV and beneficiary's QP representatives.

Figure 3. Gradation test

Figure 4. Marshall test

2. Materials

2.1 Aggregates

The aggregates used in this process, called Gabbro, are basalt crushed stone, with an almost black colour. They have the optimal physical and mechanical characteristics, according to the requirements from the job specifications, for a good quality of the asphaltic mixtures. For each new incoming supply all necessary tests are performed: gradation, elongation, chemical tests, water absorption, sand equivalent.

Figure 5. Aggregate stocks

2.2 Filler

The filler is extracted at the asphalt plant from the used aggregate, especially those with a small size (0-5) mm.

2.3 Bitum

The bitumen used in this project is harder, with a 60/70 penetration, which confers higher stability to the asphalt mixtures under specific applications, in areas with high temperatures and heavy traffic.

Figure 6. Bitumen tanks

3. Asphaltic mixtures

The roads in this project are designed with heavy bituminous pavements, in order to resist to climatic factors and comply with all requirements of resistance, flatness and roughness from the job specifications.

3.1. Mixture design

The asphaltic mixture was designed according to the Marshall method. This method takes into account the type of bitumen, the quantity of bitumen introduced in the mixture, in order to obtain the necessary density and flow, so that an adequate stability of the asphalt layer under the effect of heavy traffic and high temperatures is obtained.
The stability determined on Marshall specimens and on cores from the layed course, represents the maximum load resistance of the specimens. Creep represents the deformation of the specimens during the flow.

The stability value increases with increasing amount of bitumen content, up to a maximum and than decreases. The bulk density curve is similar to that of stability. The volume of voids decreases proportionately with increasing bitumen content, up to a minimum.
The minimum content of binder results when the stability and density attend a maximum and the volume of voids a minimum.

On completion of the optimal design of asphalt mixtures those mixtures which simultaneously have very high stability and very low values of creep shall be avoided, because the bituminous layer with these characteristics tend to be more rigid and can crack under traffic.

To ensure the covering of all aggregates by the thin layer of the compound of filler and bitumen, the optimum mixing time has been fixed at 6 seconds for the dry mixing, respectively 40 seconds during and after bitumen spraying (wet mixing). The total mixing time is 46 seconds. This time mixing ensures that all units are fully coated with the compound of filler bitumen.

3.2. *Application of asphaltic mixture*

The road pavement consists on two layers:

- Base course - with a thickness range of 21- 36 cm, depending on the area;
- Wearing course – with a 4 cm thickness.

The base course is implemented in stages, each layer being 10,5 cm thick. These 2 or 3 layers of asphalt base course serve to retrieve the loads caused by the traffic, especially tangential efforts and tensile strength and to make the link between layers.
At least 24 hours before asphalt laying, one thin layer of prime coat MC70 is sprayed on the subbase, about 0.7 kg/m².

Figure 7. Priming with MC70

The asphalt temperature during the transport is 145-160˚ and before compaction is about 130˚.
The asphalt laying is achieved through 5 computerized finishers. Each finisher is accompanied by a heavy steel roller and 3 tire rollers. The steel roller has the role to fix the laid asphalt, the tire rollers are for asphalt compaction until the required density is achieved.

Figure 8. Asphalt laying

Figure 9. Bituminous layer compaction

3.3. Tests performed on mixtures

Every production day, several visual tests on asphalt are performed, to verify if the aggregates are complete and very well covered by a thin layer of the compound of bitumen and filler.
Also, at least one specimen per day of produced asphalt should be taken, in order to proceed the Marshall test. So far (425 days of production) more than 500 Marshall tests have been made.

Table 1: Average results of tests on bituminous mixtures

TEST		Type of asphalt			
		Base Course		**Wearing Course**	
		Result	Specification	Result	Specification
1	Bitumen content % from mixture weight [%]	3.6	3.5 ± 0.2	3.8	3.7± 0.2
2	Density [kg/m^3]	2582	—	2546	—
3	Maximum Specific Gravity	2.722	—	2.725	—
4	Air Voids [%]	5.1	4 — 8	6.6	5 — 8
5	Voids in Mineral Aggregate[%]	14.1	>13	16	>15%
6	Voids filled with bitumen [%]	64.1	50 — 70	58.7	50 — 70
7	Compacted aggregate density [kg/m^3]	2.491	—	2.449	—
8	Stability [kN]	18.0	—	15.0	—
9	Corrected Stability [kN]	17.80	>9.0 K	14.8	>10
10	Flow [mm]	3.00	2 — 4	2.6	2 — 4
11	Stiffness [kN/mm]	6.3	>4.0	5.8 K	>4.0

From table 1 it is clear that all results are complying with the requirements in the project specifications. In the same time they are complying with the requirements for bituminous layers in hot areas, as the State of Qatar and for heavy traffic load in this project, considering that the roads in this project will carry heavy loads of the received or sent materials through the RLC port.

3.4. Tests on cores extracted from the layed asphalt

After laying and compaction of asphalt, before being set in operation, cylindrical samples shall be taken, by drilling, as in Figure 10, to check the aphalt layer thickness and the density after compaction (compaction degree).

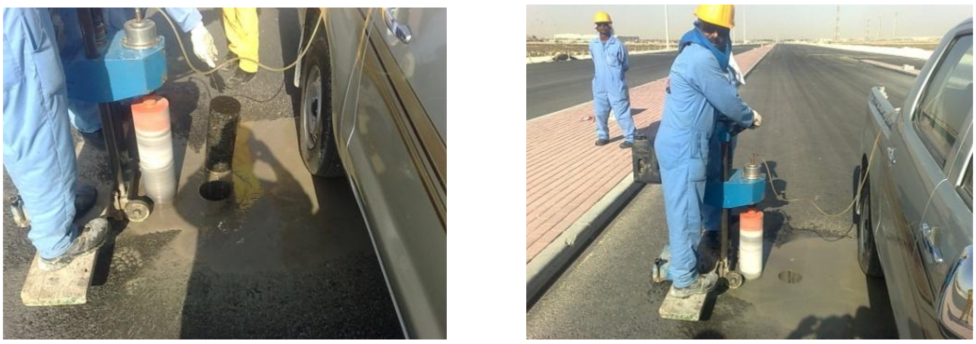

Figure 10. Sampling from the layer

This kind of test should be applied for every 1000 m² at least, and two samples should be taken for the same location. The obtained results for density are ranged between 98% and 100.5% of the density of the mixture designed in the laboratory, the acceptance condition is between 97% and 101%.

Figure 11. Cores from the achieved layer

The thickness of the base course was generally between 10.5cm si 12 cm, and the thickness of the wearing course about 4.5cm.

The thickness of the base course exceeded in a few places the thickness limit which should be less than 11 cm to obtain the admissible compaction, but at the same time the density was between the limits of good quality. This was related to the following reasons:

- the asphalt temperature at laying was no less than 130^{o} C;
- the aggregates have low abrasion(7%) and water absorption 0.5%;
- the filler - bitumen ratio is suitable;
- compaction time was appropriate to obtain the required density;
- the aggregate gradation is within the limits of good quality.

4. Analyse of the tests results

The aggregates are of good quality, natural, their graduation meets acceptance limits, water absorption is 0,5% and abrasion is 7%, so the results of all tests were very good and within the

limits.
The filler is extracted from the same aggregate, a great advantage we have here is that the filler is fresh, direct from the drier to the mixer.
The bitumen is 60-70 penetration. This bitumen with low penetration is suitable for the areas with high climate temperatures more than those with higher penetration, increases the asphalt mixtures stability and prevents the danger of the waves appearance.

The average percentage of voids was 5.1% for the base course, and 6.6% for the wearing course. These percentages ensure an asphalt pavement durable, waterproofed, and superior physical-mechanical performances.

The average filler bitumen ratio was 1.3 in the bituminous base course, and 1.14 for the bituminous wearing course. The filler-bitumen ratio is very important in the asphalt mixtures, especially on physical-mechanical properties of asphalt mixtures, but it is more important when this asphalt will be used in hot areas like Qatar. The excess of bitumen ratio leads to several effects on workability, compactness and mechanical stability of asphalt, during the road using at high temperatures. Also the excess of bitumen will lead the bitumen to appear to the road surface.

The bitumen content is 3.5% for the base course, and 3.7% for the wearing course. At first sight, it can be said that the bitumen content is too small, but considering the fact that aggregate abrasion is 7% and water absorption is 0.5% , this content is suitable : is not too small (to reduce the compressive strength or not covering the aggregates with bitumen). In the same time, it is not too hogh (to cause deformation in asphalt mixtures and to decrease the bulk density or the voids volume). Also, for roads with heavy and rush traffic, the percentage of the binder in the asphalt mixture should be limited to the lower dosage.

The mixing time is adjusted to be enough for full coverage of the aggregate with the bitumen, and so is the heating temperature - 185˚ for aggregates and 165˚ for bitumen. Asphalt temperature during the transport to the site is 145-160˚, during laying it is 140-145˚ and direct before compaction is nearly 140˚. The mentioned temperatures are suitable in all stages, especially before and during compaction, to obtain the required density and the voids percentage. The asphalt pavement is protected from the rainwater by 2% cross slope and gullies on the both sides of the road.

5. Conclusions

From all mentioned data and results, it can be noted that the obtained pavements are durable, waterproofed and superior physical and mechanical performances. The test results fall within the technical specifications of the project and standards for hot areas with heavy traffic.

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STRUCTURE AND BUILDING FAÇADES. THE NEW CONCEPT OF ORNAMENT

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Abstract

The chosen structural system and the structural element can be implicated in different ways in the composition of the façades; their implication is determined by the concept of structural design in the architectural aesthetics. The concept of ornament in today's architecture has different manifestations, for the purpose of anchoring in the cultural phenomenon, the idea of expressivity through consistency and not just decorum. The ornament is not considered anymore to be a prior determined mask, to create a significance, to have a certain meaning, the way it manifests itself in the Postmodern Period, it doesn't have the role of concealing something, the way it happened in different historical periods prior to the modern period, when its existence was futile. Contemporary architecture produces "communication" through ornament, which manifests itself in different depths of the covering layer of the façades. The technological performance and the new digital techniques in building design, have determined a close relationship between structural engineering and architectural aesthetics.

Rezumat

Sistemul structural ales şi elementele structurale pot fi implicate în diferite moduri în compoziţia faţadelor implicarea acesteia fiind determinantă prin conceptul de design structural în estetica arhitecturală. Conceptul de ornament în arhitectura actuală capătă diverse manifestari, iar acesta are ca scop ancorarea în fenomenul cultural, ideea de expresivitate prin consistenţă şi nu doar un decor. Ornamentul nu mai este considerat o mască determinată apriori, pentru a crea semnificaţie, a avea un anume înţeles, în felul în care se manifestă în perioada Postmodernă, nu are rolul de a ascunde ceva, aşa cum se întampla în diverse perioade istorice anterioare perioadei moderne în care existenţa acestuia era inutilă. Arhitectura actuală produce "comunicare" prin ornament, acesta manifestându-se în diferite profunzimi ale stratului anvelopant al faţadelor. Performanţele tehnologice şi noile tehnici digitale de proiectare a construcţiilor, au determinat o relaţie strânsă între ingineria structurală şi estetica arhitecturală.

Keywords: concept, ornament, perception, façade, structural design

Introduction

The façade is responsible for the visual impact of a building, as the covering, as the interface between the viewer and the built space that has a purpose, a signification and a context. The compositional aesthetics of architecture has been explored through the course of time, in extremely

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diverse ways from one historical period to another.

The modernism of the beginning of the 20th century uses as a main idea, “transparency” [1] in order to obtain a direct representation of the architectural elements of the built space, of the architectural program and of the structure generating the concept of “architectural sincerity”. Later on, Postmodernism uses de concept of decorum, allusion, significance and Deconstructivism uses the geometry of collage, replacing the idea of transparency of the modernism. Currently, the idea of expressivity has become an objective to architecture, in a general context where the image is the main communication vehicle of the consumer society, which involves a number of constraints regarding the reevaluation of the necessary instruments for the construction of a building’s expressivity. Many new architecture programs have come up in the catalogue of building purpose, following the specificity of the social urban context of our days which is characterized by speed and communication. We are witnessing the emergence of a growing number of buildings the purpose of which does not require an exterior-interior relation that is defined by the covering, who’s façade is opaque, without transparency, interior cores, small polarizing centers that concentrate the functions of the city on a small scale. These buildings belong to the category of media centers, offices, malls, movie theatres, museum, libraries, etc. Contemporary technology concentrates on controlling the environment, on the energy efficient spaces, objectives that involve concentrating the design on the dimension of the spaces, of the covering and its relationship with the natural light and the bearing structure.

Structure and building façade

Making such buildings, contemporary as a complex system, that integrate the relationship of the interior space with the architectural volume as well as the relationship of the interior space with the urban context of the building, brings to the attention the performance of the element that mediates these relationships, namely – the covering, the façade of the building. The performance of a façade is assessed through aspects regarding the capacity in which the natural light relates with the interior space, aspects regarding the capacity to maintain the thermal efficiency of the building and the thermic comfort and least but not last the capacity to offer aesthetical value through expressivity and composition.

The role of the structure is multiple: firstly is providing stability and resistance, then is the role of sustaining the architectural aesthetic concept in the façades; another important role is that of the quality of the interior space, through the capacity of rhythm, distribution, liberation and maximizing the flexibility of the interior spacial configuration and also to allow for a good relationship with the natural light in the façade. So, the chosen structural system and the structural elements can be involved in the composition of the façades in various ways.

Using representative examples of architecture from across the time and a periodization specific to most important publications in the field of architectural history, three important instances of the relationship between structural form and architectural image can be distinguished in the universal architecture, namely:

1. The visible structural form – situation in which the structural elements can be identified visually in the image of the architecture participating alongside other elements of compositional and ornamental order, to the general form of the building. (Fig. 1)

Figure 1. The Sendai Mediatheque, Sendai, Japan, Toyo Ito, 2001

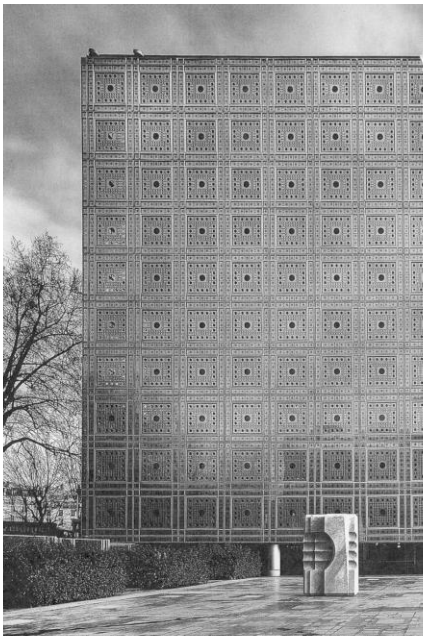


Figure 2. Institut du Monde Arabe, Paris, France, Jean Nouvel, 1987

2. The hidden structural from – situation in which the existent structural elements don't participate in the image of the building, being in the « architectural covering » not having a role in the composition, the invisible structural form doesn't coincide with the apparent contour of the building. (Fig. 2)

3. The determinative structural from – situation in which it generates the compositional volume concept of the architecture, determining the architectural from and implicating itself in the details and ensemble of the architecture. (Fig. 3)

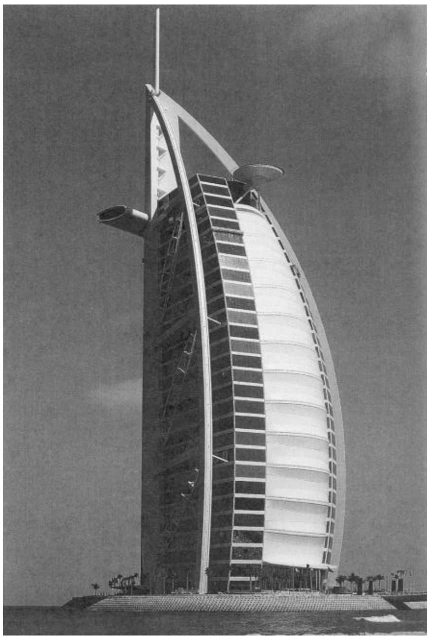


Figure 3. Hotel Burj al Arab, Dubai, UAE, Arkins, Epsom, 1999

All these demonstrate the certainty of the implication of structure in architectural aesthetics, determined through image in various ways and various degrees of participation.

Architectural aesthetics is concerned with beauty in the art of architecture. This premise places architecture among the visual arts, receiving aesthetic value it fits in the aesthetic markers characteristic to the area of general aesthetics and its theories.

Defining architecture in the field of aesthetics and philosophy, in different historical periods and then confronting these definitions with the characteristics of the architecture of those periods, relationships between architectural form, aesthetics and structural form can be identified.

The aesthetic attribute, followed in the study of architecture, demonstrates the relationship it has with structural from, in order to respond to the request of beauty that is addressed to the field.

Nature, interpretation, creation and the reception of «beauty» in architecture, from the point of view of architecture as an artistic phenomenon of some personalities form the field of philosophy, aesthetics and architectural theory, is an important analysis that underlines the aesthetic role that the structural element and structural system can have in the compositional concept of architecture in different historical periods. Also, the identification of certain moments of change in the definition of architectural aesthetics, such as the one form the beginning of the 20th century when architecture accentuates its functional role, certifies the importance of structure in defining architectural space and its aesthetic qualities. Various classifications of architectural space elements and the various ways of receiving it in the modern period, determine the link between the evolution of structures, of geometry of structural shapes, of technological performance and of new materials that have made the evolution of the architectural phenomenon and as well as the aesthetic perception in the field possible.

Architectural elements have determined the evolution of structures, the relation between the geometry of shapes and the static function of the architectural structures and the relation between structure and the architectural image.

Table 1. *The structure-image relationship throughout different architectural historical periods.*

Historical period in architecture	**Architectural special characteristics**	**Structural characteristics**	**Structure/Image**
The primitive period	Labyrinthian agglutinated multiplied	Wood structures, clay, stone, simple	Visible
Greek antiquity	Composition , proportion, order	Transposition of the wood trilithic system into stone	Visible
Etruscan roman antiquity	Large dimensions, monumental	System of columns, arches, domes	Determinative
Early christian period	Simplicity, interiorization	Dome, vault, christian capital	Visible
Romanesque (early gothic)	Complexity, massiveness	Round arches, thick walls	Visible
Gothic	Space, height, stone lacing, spatial liberation	Simple arches, ogival arch, selfsupporting long columns	Determinative
Renaissance	Proportions, pure shapes	Pediments, flat ceilings	Visible
Baroque/ rococo	Sculptural, complexity	Pilasters, pediments, keystone	Hidden
Neoclassicism (romanticism)	Proportions and classical orders, monumental	The interpretation of anchient architectural structure	Hidden
The modern period	Functional, free, transparent	Reinforced concrete structure, cast iron, steel bearing structure	Determinative
Contemporary	Stylistic pluralism, compositional diversity	Different typologies, structures, structural innovations, new technologies	Visible, hidden or determinative

In early times, the clarity of the shapes and the equilibrium of the proportions have been favored, as opposed to the complex drawing of gothic buildings. Mathematical relations have been used to establish harmony. A preference for symmetry and pure forms is established at the same time with the rational approach of projects. The study of perspective has allowed architects to progress in the display of objects in relation to spatial perception.

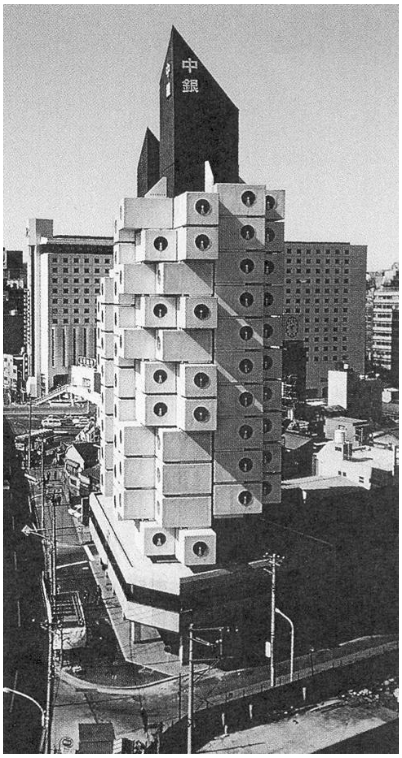
The new concept of ornament

The image of a building has always been determined mainly by aesthetic, formal criteria that are left to be satisfied by the architect. Along history, the idea of ornament as a decorative element with an aesthetic role had different positions in relation with the principals of each architectural style. The ornament, as a visual element that belongs to the façade, is known in the history of architecture due to the opposition between Gottfried Semper and Adolf Loos' theories. For Semper, the functional and structural aspect of a building is second to that of aesthetic and artistic aspect of the ornament. On the other hand, for Adolf Loos, the ornament was futile, leaving in history the famous slogan "ornament and crime". This moment the history of architecture marked a new attitude towards the idea of ornament in the image of building façades. According to Loos, the ornament has been used by the traditional society as a way of social differentiation, whereas the modern society didn't have as an objective the exacerbation of individuality, but contrary, its suppression. So for Loos, as soon as the ornament lost its social function, it became futile.

The modern period from the beginning of the 20th century, brought to the attention transparency as a way to make the architectural image much more honest, in contrast to the bourgeois decorativism. This characteristic has dominated the architectural image up to the '60s.
In the following period, Robert Venturi and Denise Scott Brown denounce the paradigm of modernism as being cynical and limited as propose the replacement of transparency with decorum. For them, the architectural decorum of the façades helps with the integration of the buildings in the urban objectives and offers significance to the public eye. A rupture is born, between the idea of building as function and building as representation accepting the contradiction between space, structure and building purpose as a creative factor. In this period, architects seek an architectural expressivity that is separated from the spacial organization; the cultural expression "ready-made" [2] is now incapable of communicating with an intelligent and dynamic public. But postmodernism lost its strength and impact due to the absence of a language or system of understanding. The symbols that were used remained anchored in the particular cultural moments or certain contexts that couldn't survive the changing conditions of the following periods. For architecture to remain convergent with culture it has to build mechanisms through which culture can produce new images and concepts, rather than recycling the existing ones.

In contemporary architecture, the concept of ornament acquires various manifestations with the purpose of anchoring in the cultural phenomenon, the idea of expressivity through consistency and not just decorum. The ornament is not considered anymore to be a predetermined mask, in order to create a significance, to have a certain meaning, in the manner in which it manifested itself in the Postmodernism period, it doesn't have the role of hiding something, the way it happened in various historical periods[3] prior to the modern period when its existence was futile. Contemporary architecture produces "communication" through ornament, which manifests itself in different depths of the covering layer of the façade. The classification of the manners of manifestation of the contemporary ornament can be made according to the relationship it has with the constructive system of the building, considering the type of material it is made of and according to the effects it creates from a visual point of view. The analysis of the three situations underlines the link between them: constructive system, the texture of the material, material – affect.

A) The concept of ornament related to the constructive system manifests itself on the level of architectural form, on the level of the structure, as a screen – partition wall that separates the interior space form the exterior, or as an applied surface.
1) *The ornament resulted from shape (a),* includes those architectures whose entire volumetric, plane and spacial organization determines repetitive elements in the façade that emphasizes the surface of the covering in an expressive manner. This type of ornamentation obviously implies choosing a structural system and certain structural typologies that best define the formal concept of the architecture. (Fig. 4)



1. Circular base plate, 140 mm dia., glued to glass
2. 2-piece inner guide ring, polished brass, with screws
3. Circular inner cover plate 120 dia. X 5 mm, with screws
4. Divider, 1.2 mm sheet metal
5. Frame, 2 mm sheet aluminium, bent to suit
6. Plastic-coated paper
7. Aluminium retainer with clip
8. Outer guide rail
9. Fixing, attached to window reveal
10. Theraded sleeve, 20 mm dia.
11. Fixed light, 6 mm toughened safety glass, 1300 mm dia.
12. Rubber gasket
13. Sheet aluminium, screwed to aluminium angle, 40 x 40 x 4 mm

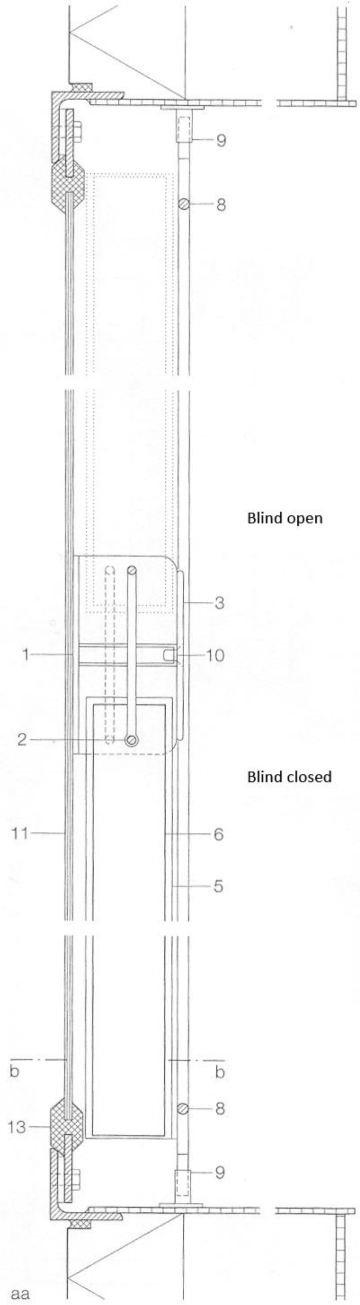
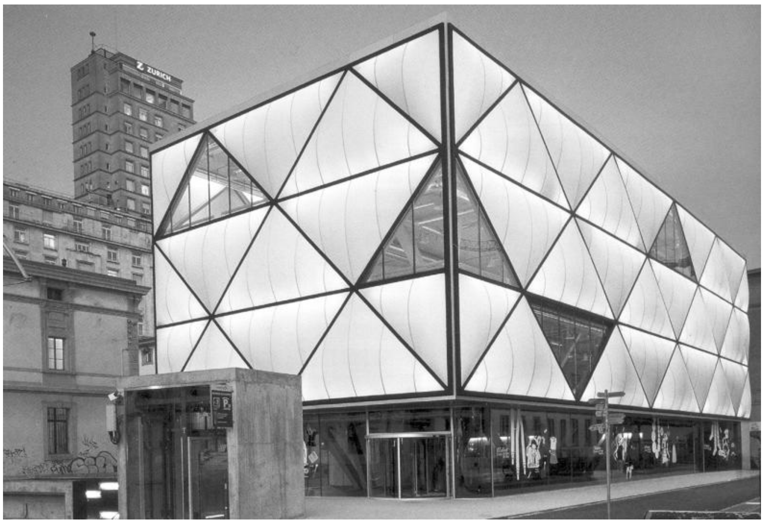


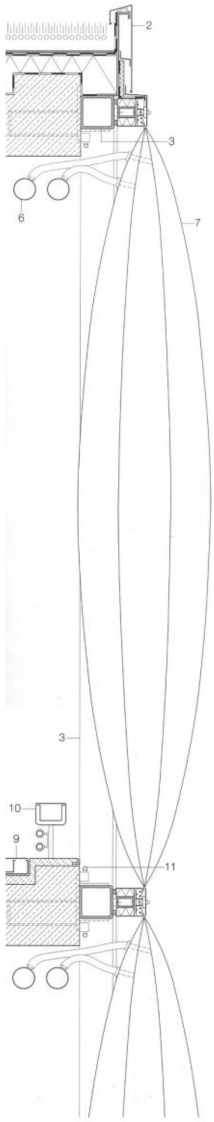
Figure 4. Nakagin Capsule Tower, Tokyo, Japan, Kisho Kurokawa & Associates, 1972

2) *The ornament resulted from structure (b)* includes those instances when structural elements are visually involves in the façade of the building. The shape of these structures resulted through calculus, through choosing a certain typology and a certain material creates an ornamental texture of the building covering. (Fig. 5)

3) *Ornaments that result from the structure of the enclosing system (c)* involve the layers that are interposed between interior and exterior of the walls and participate visually-expressive in the interior as well as in the exterior. In this case, the structure is not visible but it has the role of ensuring a solid-hollow relation in the walls. (Fig. 6)

4) *The surface ornament (d)* is that which is applied independent from the enclosing system, a separation of the interior form the exterior space, on the exterior side, visually participating only to the external environmental context. In this case, the structure doesn't have an apparent visual role, but only that of resistance in association with the enclosing elements that are involved. (Fig. 7)





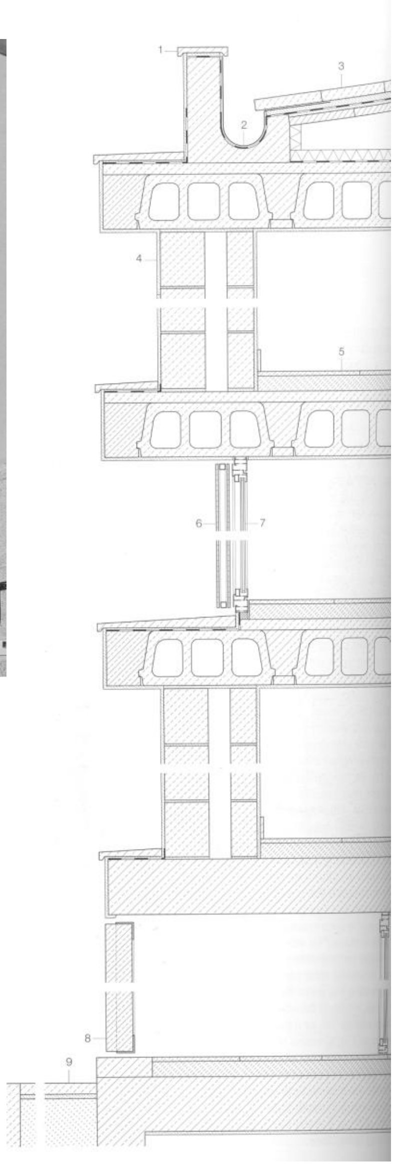
1. 50 mm extensive vegetation layer
   80 mm mineral plant substrate
   10 mm drainage layer, elastomer 2-layer sealant
   180 mm foam glass insulation, bituminous treatment
   vapour barrier
   280 mm reinforced concrete pre-stressed roof slab
2. aluminum sheet metal
3. 150/150 mm steel SHS
4. sprinkler
5. cable trough
6. pressurized air pipes
7. façade element, membrane cushion,
   4-6 mbar pressurized, U value = 1.3 W/m^2K
   1x membrane PTFE white,
   3x membrane ETFE translucent
8. 70 mm screed; 40 mm insulation
   280 mm floor slab, reinforced concrete
9. floor duct
10. heating
11. fluorescent lighting
12. ventilation duct

Figure 5. Commercial Building, Laussanne, Switzerland, B+W architecture

4) *The surface ornament (d)* is that which is applied independent from the enclosing system, a separation of the interior form the exterior space, on the exterior side, visually participating only to the external environmental context. In this case, the structure doesn't have an apparent visual role, but only that of resistance in association with the enclosing elements that are involved. (Fig. 7)
B) The concept of ornament according to the used material is different for the enclosing elements of the façades. The quality of the chosen material, the processing technology, the way in which it can associate with the desired shape, the tradition and the significance it has, are equally important in the making of façades.

The technological evolution and structural inventiveness have determined a great diversity of architectural expressivity. Creating diverse architectural shapes is ties to the new structural concepts, as well as to the discovery of performant building materials that make it possible. The evolution of building materials technics consists of improvements to the physical-mechanical characteristics of the classical materials as well as the invention of new materials.

Composite materials are made by integrating elements that belong to materials with different properties in various ways, either through associating of a matrix, either through association following the sandwich principle, by inserting a light material between two sheets, composition following the organic structures model or through obtaining of films, plates or extruded profiles.

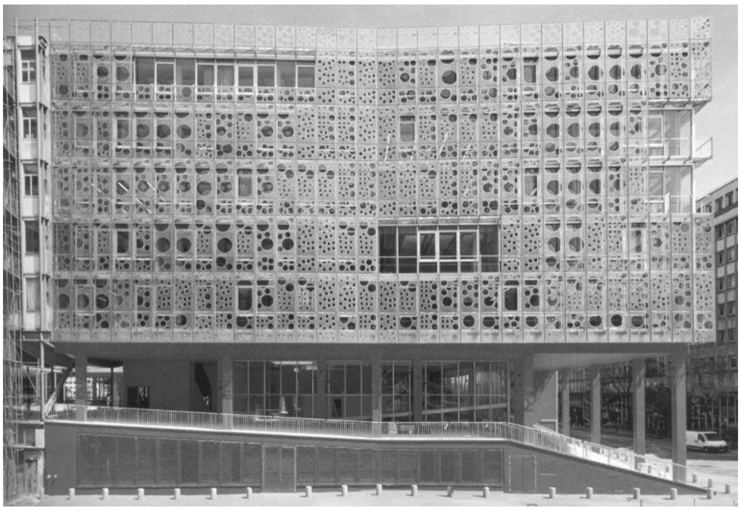


1. polymer concrete clapping
2. PVC rainwater gutter
3. roof construction:
   50/300 mm concrete slabs
   30 mm protective layer
   with mineral coating
   15 mm bed of mortar
   40/400 mm ceramic slabs
   ventilated space
   50 mm extruded polystyrene
   thermal insulation
   vapor-retarding layer
   50 mm concrete topping
   250 mm hollow concrete floor
   15 mm gypsum plaster
4. white latex coating
   15 mm mineral rendering
   200/250/500 mm concrete
   Block wall ventilated cavity
   (varying depth)
   120/250/500 mm concrete block
   wall
   15 mm mineral plaster
5. 20 mm terrazzo floor slabs
   400/400 mm; 70 mm screed
   50 mm concrete topping
   250 mm hollow concrete floor
   15 mm plaster
6. folding shutter: 2x 10 mm high-pressure-laminate sheets on 40x40 mm steel SHSs
7. double glazing in aluminium frame: 2x 6 mm toughened glass + 4 mm cavity
8. 120 mm exposed concrete door
   80/80/5 mm steel angle surround
9. 50/400/400 mm concrete tiles on
   leveling layer
   300 mm bed of sand

Figure 6. Publicly Assisted Housing, Vecindario, Spain, Pedro Romera & Angela Ruiz

The making of high-performance concrete by replacing traditional reinforcement with steel tubes filled with concrete, or the post-tensioning of high-performance concrete for the placement of buildings with large spans, fiber reinforced concretes which due to the lightness of the material allow fabrication through pulverizing of very thin surfaces, method that argue the comeback of the expressive and spectacular concrete membranes in contemporary architecture.

As a building material, glass has a multiplied role today; it can be the covering, an interface between the interior space and the environment, a support for a large range of colors, textures and images, creating a screen for communication. Smart materials[4] obtained through film technics and nanometrics, bring exceptional plastic qualities to the building façades, through phototropic glass, photochromatic or glass with integrates circuits, as well as electrochromatic glass, that changes its transparency and translucidity. Structural glass walls, the history of which started with the first façade made from structural glass in 1986 at the Great Greenhouses at the Science and Technology Museum, in the La Villette Park (arch. Adrien Frainsilber and eng. Peter Rice) that use cable rods for stabilizing the glazing and the glass clamping system, which imposes a dissociation condition of the joint glass panels in order to allow movement and sealing with silicone or elastic neoprene bands, as well as the necessity of assembly only with elastic joints or spherical joints for spot fastening.



1. 2 mm rubber surfacing
   330 mm reinforced-concrete slab
2. 30/30/2 mm galvanized steel grid
3. bracket, steel SHS 80/80/3 mm
4. 2 mm aluminium sheet
5. curtain rail, galvanized steel profile
6. post, 60/50/4 mm steel channel section
7. façade element 1800 and 1000 x 1200 mm
   3 mm perforated aluminium sheet
8. emergency opening, aluminium window
   with insulated glazing
9. handrail, 40/40/2 mm steel SHS
10. 4 mm Ø stainless-steel cable
11. railing profile, 3 mm bent steel sheet
12. external solar protection

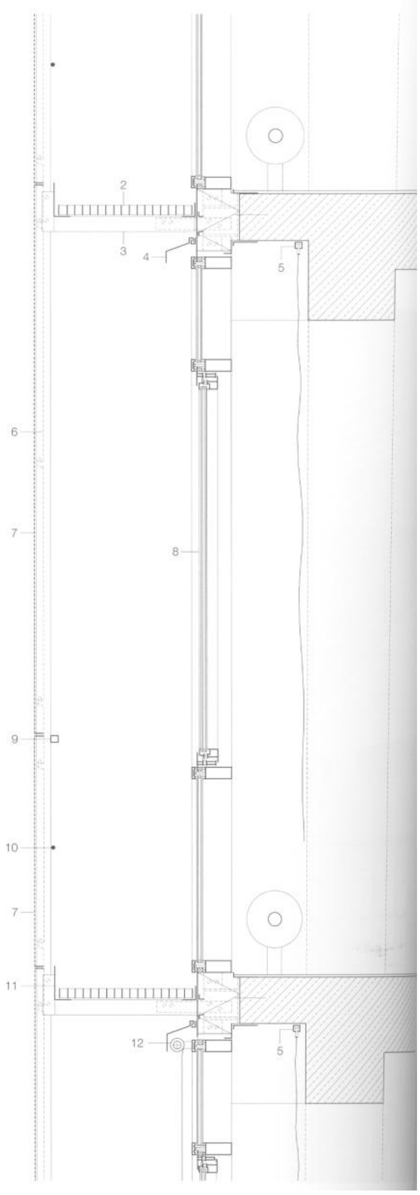


Figure 7. University Building, Paris, France, Peripheriques architectes

C) The concept of ornament after the visually-plastic effect is another criterion. The visual effect is the result of the connection between the constructive system in its different manifestations and the quality of the chosen material. Contemporary architecture progressively concentrates on the expressivity of the building covering, the specificity of the constructive material of the façade elements seeking the sensational and affect. Recent architectural experiments explore digital methods of visualizing the façade technology, its performance in the field of building structures and material capable of expressivity becoming the cultural force. Due to the new concept of façade ornament, the texture of the building material has the quality of producing an "Affect"[5]. Sensation and affect are concepts that belong to our perceptive structure.

1) The visual perception applicable to architectural perception can be ***suggested (a)*** with an interferential character, that refers to an information that is just sketched, that leaves the concept idea to be deduced.

2) Perception can be ***selective (b)***, that chooses certain elements to be perceived through diverse selective psychological or cognitive mechanism, a character or perception that can be speculated through elements of interest accentuated in the architectural composition that attract the attention.
3) A different way of perceiving shapes is that ***categorial (c)*** when common features, similar to the components of the architectural image are distinguished and are mentally grouped in categories with the same characteristics, the repetition of certain elements in a particular rhythm, the replay of certain elements with different compositional rules on a chromatic, textural or formal level.
4) The ***relational (d)*** character of perception refers to the comparison of certain elements that are next to each other in a system of relation, the compositional elements of architecture are in a relation of juxtaposition or overlapping.
5) The principle of ***adaptation (e)*** of visual perception in the case or architectural image refers to the concentration of attention on certain important characteristics or façade compositions, through aesthetic special effects resulted after certain compositional processes.
6) The ***evocative (f)*** character or human perception is determined by the comparison of visual elements of architectural image with others that are similar, extracted from the image of other architectures or from representative historical architectural styles.
Therefore the chosen structural system and the structural elements can be implicated in the façade composition in different ways, their implication is determined through the concept of structural design in architectural aesthetics. (Fig. 8)

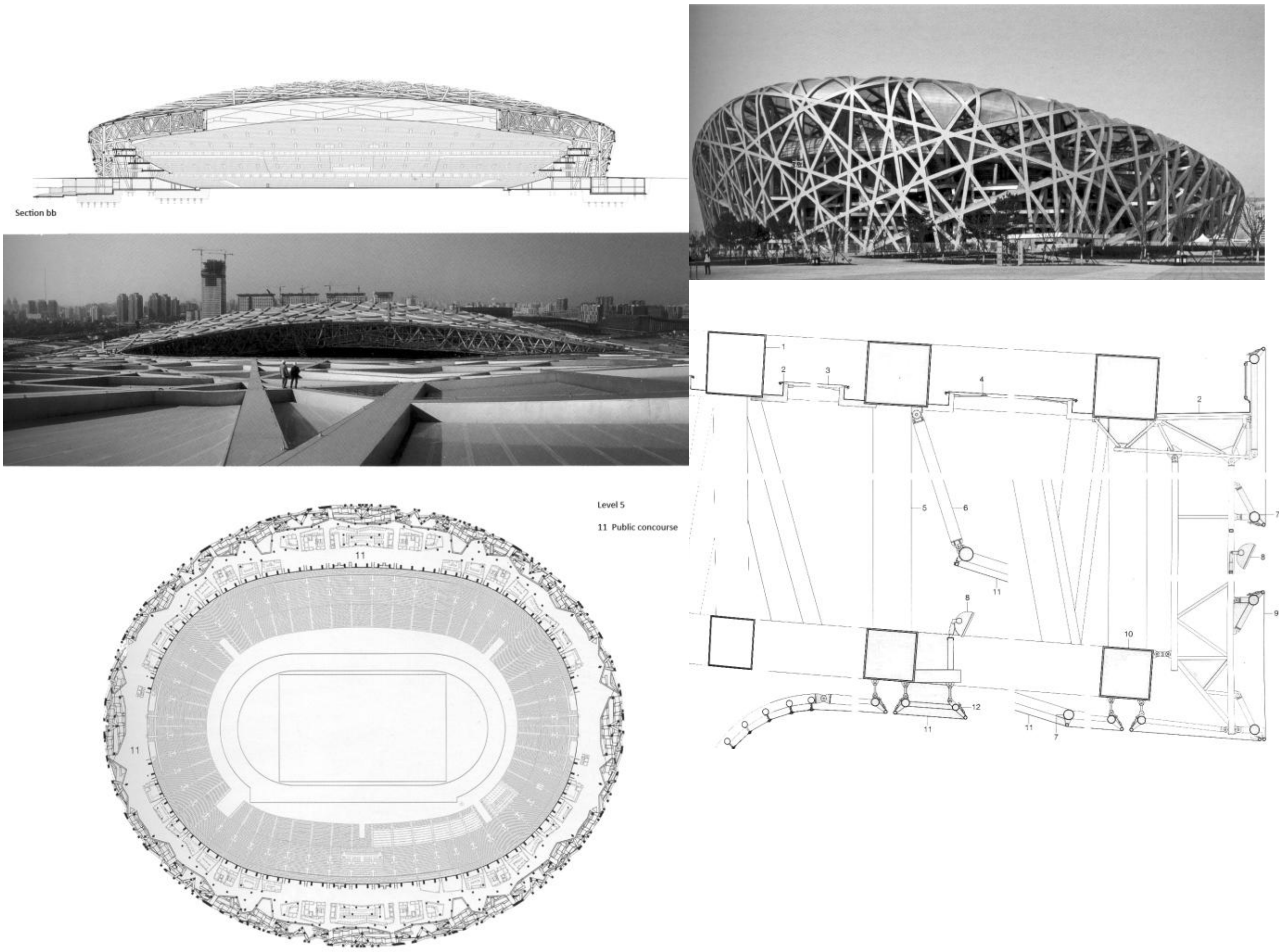


Figure 8. National Stadium in Beijing, Beijing, China, Herzog & de Meuron, 2008

Conclusions

1) The concept of ornament in contemporary architecture has various manifestations, and it has the purpose of anchoring in the cultural phenomenon, the idea of expressivity through consistency, and not only through decorum.
2) The ornament isn't considered a predetermined mask anymore, in order to create a significance to have a certain meaning, the way it manifested in the postmodern period, it doesn't have the role of hiding something, the way it happened in various historical periods prior to the modern period, when its existence was futile.
3) Contemporary architecture produces "communication" through ornament that manifests itself in different depths of the covering layer of the façades.
4) Technological performances and the new digital techniques of building design have determined a close relationship between structural engineering and architectural aesthetics.
5) In architectural creation, the way images are explored through perception has as a source the human capacity to react to a series of stimuli such as light and acoustic intensity, shape, color, three dimensionality and significance. These markers quantify the quality of architectural perception, revealing the subjective component that it contains.
6) The contemporary architectural façade is a covering conceived to satisfy the comfort and security requirements as well as aesthetic requirements that animate the built landscape, and the ornament of contemporary architecture is the reflection of the new material technologies and of technical reasoning.

Notes:

[1] Concept that defines modern architecture staring from the idea of "sincerity", developed in the publication *Transparence reele et virtuelle, Les Editions du demi –Cercle*, Paris written by C. Rowe

[2] Robert Venturi and Scott Brown argue in this manner the progressive preoccupation of architects for the architectural expression - *Learning from Las Vegas*, Cambridge, MIT press, 1972

[3] Especially in the baroque and rococo period, 17th–18th century, that developed the sculptural ornamental potential of façades

[4] Created after biological patterns, are systems that self-monitor, self-adapt and self-repair.

[5] Term used by Gilles Deleuze and Felix Guattari to define the specific of art creating sensations and affections, *"Percept, Affect, and Concept" What is Philosophy?*, New York, Columbia University Press, 1994.

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Effectiveness and efficiency of research activity

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Abstract

The main purpose of research, development and innovation (RDI) is the stimulation of operational, commercial and financial effectiveness and efficacy of companies. Its vision is: better and more, easier and faster, cheaper. Scientific research represents today the most important engine for the improvement of living conditions, health, culture and, in general, the wealth of a society. It is equally true that a healthy economic, social and cultural development is not possible without a well structured learning system with high academic standards based on a vigorous scientific research. Research and development activity aims for development or innovation of services, products and technologies, insuring an optimal compatibility between the outputs of planning these activities (objects, strategies, programs and budgets) and the outputs of planning business portfolios and business strategies, as the outputs of the operational planning of the research-development activity (projects and budgets).

Rezumat

Cercetarea, dezvoltarea şi inovarea (CDI) are ca scop creşterea eficacităţii şi a eficienţei operaţionale, comerciale şi financiare a firmelor, a cărei viziune este: mai bine şi mai mult, mai uşor şi mai repede, mai ieftin. Cercetarea ştiinţifică reprezintă astăzi pârghia cea mai importanta pentru îmbunătăţirea nivelului de trai, a sănătăţii, a culturii şi, în general, a bogăţiei unei societăţi. Este la fel de adevărat că o dezvoltare economică, socială şi culturală sănătoasă nu este posibila fără un sistem de învăţământ de înalt nivel, bine structurat, bazat pe o cercetare ştiinţifică viguroasă. Activitatea de cercetare-dezvoltare vizează dezvoltarea sau înnoirea serviciilor, produselor şi a tehnologiilor, asigurându-se o compatibilitate optima între out-put-urile planificării acestor activităţi (obiective, strategii, programe şi bugete) cu out-put-urile planificării portofoliilor de afaceri şi a afacerilor strategice, precum şi cu out-put-urile planificării operaţionale a activităţii de cercetare-dezvoltare (proiecte şi bugete).

Key words: *research, development, efficieny, effectiveness, innovation*.

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1. Introduction

Research-development function plays an important role in the activity of a company, which is highlighted by the constant consolidation and proliferation of innovative companies, companies that give a great importance to this function and gain competitive advantages on the market, making them remunerative and profitable.

The strategy for research-development activity derives from the general strategy of the company and it is established by taking into consideration some decisive factors: the action environment of the company (politic, socio-economic, technologic and commercial), creative-innovative potential, productive and marketing potential, its available resources.(Ardelean A. *et al*., 2006)

Research-development programs determine the planed objectives and strategies for research-development, define the projects that are necessary for the realization of the planed objectives and strategies, specify the terms, the time limit for the realization of the objectives and the relation between different projects, define individual or collective tasks and responsibilities that help to their realization.

2. The efficiency of public investments funds in research activity

The most important effect of increased public investments in research was the implication of the private sector in similar activities. The number of small and medium-sized businesses which have accessed public funds for RDI has increased to approximately 810 units per year in 2008; on a national level, the impact is confirmed by the growth, in the previous period, of the innovation expenditures by businesses, from 4.589 million lei to 6.421 lei – from which RD expenditures from 890 million lei to 1.456,6 lei – of the weight of businesses with innovation activity, active businesses from 19,3% to 21,2% and of the weight of employees who have an intensive contribution to knowledge, from 1,5 to 14,5.

On the other side, even though the weight of exports of high technology products (IT) in total exports has stationed at 3,8%, in absolute value, it has increased as a consequence of its increase in value; the same thing can apply to the weight of RD expenses made by the private sector. In the following table we have the impact indicators, on the structure of the National Plan:

Table 1. *The evolution of impact indicators on the economic environment*

	Indicator	UM	Reference (year)	Last value (year)
1	GDP weight of RD expenses made by the private sector	%	0,14 (2006)	0,14 (2007)
2	Weight of companies having their activity in innovation (according to Community Innovation	%	19,3 (2004)	21,2 (2006)

	Survey)			
3	Employees in IT fields manufactory industry	% total amount of employees	0,4 (2004)	5,4 (2006)
4	Employees in jobs that contribute intensively to knowledge	% total amount of employees	1,5 (2004)	14,5 (2006)
5	IT products Exports	% total exports	3,8 (2004)	3,8 (2006)
6	Number of SMBs that have accessed funds through RDI national programs *)	Number	600 (2006)	810 (2008)
7	Number of scientific parks*)	Number	7 (2006)	4 (2008)

(Source: INS*), www.ancs.ro)

The number of innovative SMBs, assisted by the Innovation program of the National Plan, has increased from 137 in 2007, to 148 in 2008 and the total amount of accessed funds, through a program of joint funding, and increasing with a factor of 4, directly proportional to their increased contribution to the projects budgets, projects included in the National Plan, from 13 million lei to 48 million lei.

The efficiency of RD system is measured by result indicators of the plans and deployed programs; their structure is also indicated in the National Plan. (The analysis of the efficiency and effectiveness of public expenses designed for research and development in Romania. Report 2009)

The number of articles having at least one scientific address from Romania which were indexed in ISI and equivalent, has increased constantly, from 5030 in 2006, to 7005 in 2007 and to 8938 in 2008, and the highest contributions, last year, were made by the National Plan, the programs: *Idei (Ideas)* – 1494 articles, and *Resurse Umane* (*Human Resources)* – 523 articles, and also by the NUC – 431 articles – and the Romanian Academy programs – 780 articles. The CEEX contribution was also extremely important, counting in 2006, when the actual National Plan wasn't launched yet, approximately 1500 scientific articles (table 2).

Table 2. *Result indicators for the evaluation of the RDI system*

	Indicator	UM	Reference year 2006	2008
1	Romanian ISI rated journals	Number	11	54
2	National patents requested/ granted	Number	965/527	867/484
3	International patterns requested/granted (EU, USA, Japan)	Number	38/11	ND
4	Number of transferable products	Number/year	ND	ND
5	International RD projects participations (Funds attracted by international RD projects)	Number (thousand Euros)	478*) (57.000)*)	181**) (30.000)**)

*)for all PC6 projects

**)Situation in 2008, the amount represents the cumulative values of the contracts with partners from Romania

(Source: ISI WEB of Knowledge/Science – Thomson Reuters, ANCS)

Economic added value is reflected in the contribution of Romanian entities to the number of requested patterns, which is 256 with backing from the National Plan, especially by the program *Inovare (Innovation)*, from which 12 are international, and 65 with backing from NUC; these numbers represent approximately 30% of the requested patterns. CEEX program contributed with 82 requests from which 25 were already granted. Other results are reflected in products, technologies, and innovative services: 630 obtained with backing from the National Plan, 230 elaborated by the national institutes, with backing from NUC and 3050 obtained within CEEX. These results are completed by a number practically equal of studies, guides, technical books etc., useful for the economic operators, influencing the weight of employees in the IT industry at a national level, growing from 0,4% to 5,4% (table 3).

Table 3. *Scientific papers and ISI quotes*

	Indicator	UM	2006	2007	2008
1	Scientific papers published in ISI rated journals - WoSci	Number/year	5030	7005	8938
2	Quotes in ISI rated journals	Number/year	18038	19869	26966

(*Source*: ISI Web of Knowledge – Thomson Reuters)

Scientific productivity reflected in the number of articles in ISI-rated journals per certified researcher aims to unity in 2008. Thus, the number of ISI rated publications edited in Romania increased to 54, from 11 in 2006.

The increase of research activities, stimulated by economic growth until 2008, and by governmental politics in the field, has led to an increase of the number of jobs for people with higher education, demand satisfied on one hand by the emergence of new researchers on the job market, and on the other hand, by the return of some researchers who were working abroad. Compared to 2007, in 2008 the number of R&D employees taking part in the programs of the National Plan has increase with 3391, respectively 181 new employees within NUC; and even though the staff of the Romanian Academy has remained practically constant, there is an increase in the number of awarded PhDs.

In the RDI system there has been an increase in the number of researchers with approximately 2%, and of PhDs with approximately 15%, an important contribution had the National Plan, thanks to the department of human resources dedicated to the PhD candidates, where almost 400 PhD theses were completed in 2008, and the Romanian Academy with 98 diplomas awarded. The structure of research has changed, there has been an increase in the number of young researchers, under 25 years, from 2,7% to 3,0% and of women from 43,2% to 44,7%.

The public investment in the R&D infrastructure had a conclusive contribution to the modernization of research laboratories in the public institutions, with backing from the National Plan, with a contribution of 435 million lei in 2008 – including the access to international research installations -, and 220 million lei from the CEEX program, 40 million lei from NUC, 32 million lei for the installations of national interest, thus the cumulative amount of these contributions has increased more than six times the amount in 2006. (The analysis of the efficiency and effectiveness of public expenses meant for research and development in Romania. Report 2009)

Table 4. *Indicators for the evaluation of the RDI systems capacity*

	Indicator	UM	Reference year 2006	Value 2008
1	Number of PhD's	Number	12 309	14 228
2	International mobilites	People/month	ND	ND
3	National mobilities (within the sector or between sectors)	People/month	ND	ND
4	Investments in the RDI infrastructure coming from national public funding (weight in total RD expenses from national public funding)	Thousand lei (%)	115 700 (10,1)	728 600 (35,0)

(*Source:* INS, ANCS)

3. Determining efficiency of the scientific research activity and technology development activity

Regardless of the research field and the instruments applied, the methodology for assessing economic impacts has to cope with three exigencies:

- to create a fundamental instrument of the activity within the system, which allows to make a decision concerning the funding and the organization in the field;
- to act like a control instrument within the research process (for possible corrections);
- to be used as a final element for assessing the contribution of the "science" field to the socio-economic development.

The economic efficiency of a theme in the technological research development system is to be calculated in at least in three specific moments:

1) at the research program inception phase, when an estimated efficiency will be calculated; currently this type of efficiency uses information already existent, as a result of the selection of the research themes;
2) at the end, when the research is completed, meaning that a viable solution has been obtained, the potential efficiency will be calculated.

This type of efficiency is suggestively expressed by calculating the indicators:

Economic efficiency coefficient:

$$K_e = \frac{U_a}{C_0 + C_a}$$

In which:

U_a = economic effects summarized as additional accumulations during the economic life of the obtained solution,

C_o = expenses during the research phase,
C_a = expenses during the economic application phase,

The term for recovering the costs of research, which represents the moment when the promoter of the research (bank, budget, the incomes of an organization etc.) will be refunded in the form of accumulations, for the credit offered to the technological research and development field:

$$T_{Rtema} = \frac{C_0 + C_a}{\frac{U_a}{V}}$$

In which:

V = economic lifetime proposed for the research results (in calendaristic years).

Currently V = 3/5, and the factor $\left[\frac{U_a}{V}\right]$ = additional accumulations in one year physically experimented.

Net effects – express the benefit of the "science" products, calculated like this:
$E_N = [U_a - (C_o + C_a)]$

3) when elaborating an economic and technical study or an order form regarding the introduction of a solution in an already existent productive system, the actual efficiency will be calculated. (Plumb I., Raţiu-Suciu I., 2003)

This type of efficacy can be calculated based on the benefits obtained as a result of the increase of the production in physical volume, on the increase of price as a result of quality improvement or of a possible reduction of the unit cost of production:

$b_1 = (q_1 - q_o) \times (pv_o - cp_o)$

$b_2 = q_1 \times (pv_1 - pv_o)$

$\underline{b_3 = q_1 \times (cp_o - cp_1)}$

$B_{TOTAL} = b_1 + b_2 + b_3$

$B_{NET} = B_{TOTAL}$ – Losses (RISKS),

in which:

q_o and q_1 = physical volumes of production registered before and after the introduction of the solution in the system, the same year;

pv_o, pv_1 = selling prices before and after the introduction of the solution in the system;

cp_o, cp_1 = unit costs before and after the introduction of the solution in the system.

If we want to determinate the economic effects in the organization, we have to summarize the expenses and the additional accumulations regarding the entire activity:

$\sum_{i=1}^{n}$, in which n = the number of achieved themes (solutions), and

$\sum_{j=1}^{m}$, in which m = the number of applied solutions in the productive systems.

For expressing the quality of the activity of the researchers in the scientific research – technological development system we currently use the following indicators:
Annual expenditure/researcher:

$$\bar{c} = \frac{\sum_{i=1}^{n} C_{0i}}{n_1}$$

in which:

n_i = the number of researchers who participated in the research act during one year:

Annual additional accumulations/ researcher:

$$\bar{b} = \frac{\sum_{j=1}^{m} U_{aj}}{n_1}$$

When determining the economic effects of the scientific research – technological development for longer periods of times (1-3 years) and on different organizational levels (research organization with more branches, industry etc.) it is requested to elaborate arguments presenting the favorable factors or the limits of a complex research program. (Plumb I., Raţiu-Suciu I., 2003)

4. The risk in the scientific research and technological development activity

The rate of development of the scientific research – technological development system is, nowadays, extremely high, which imposes an anticipation of material, human and financial resources implicated in the process.

In the same time, unlike any other productive activity where we can establish *a priori* qualities, quantities, terms and costs – in other words, fabrication facts of the scientific research – the technological development activity is still having a certain probabilistic character (state determination) in the obtaining of useful practical data.

This state of indetermination in the obtaining of useful results appears in this system under the form of the risk.(Sandu S, 2002)

The problem of risk identification, its prevention or at least its diminution is justified, as the exigencies towards the economic efficiency which would be necessarily registered in this activity are increasing.

Risks are taken into consideration the entire period of the scientific research – technological development cycle and, especially, in the phase of results application in the industrial practice.

Based on recent selective researches, it is esteemed that: the expenses in the scientific research – technological development system, and, proportionally, the apparition of risks are evolving like it follows:

- in the phase of fundamental oriented research 1;
- in the phase of applicative research 10;
- in the phase of productive assimilation 100.

Figure number 1 presents the main forms of risk.

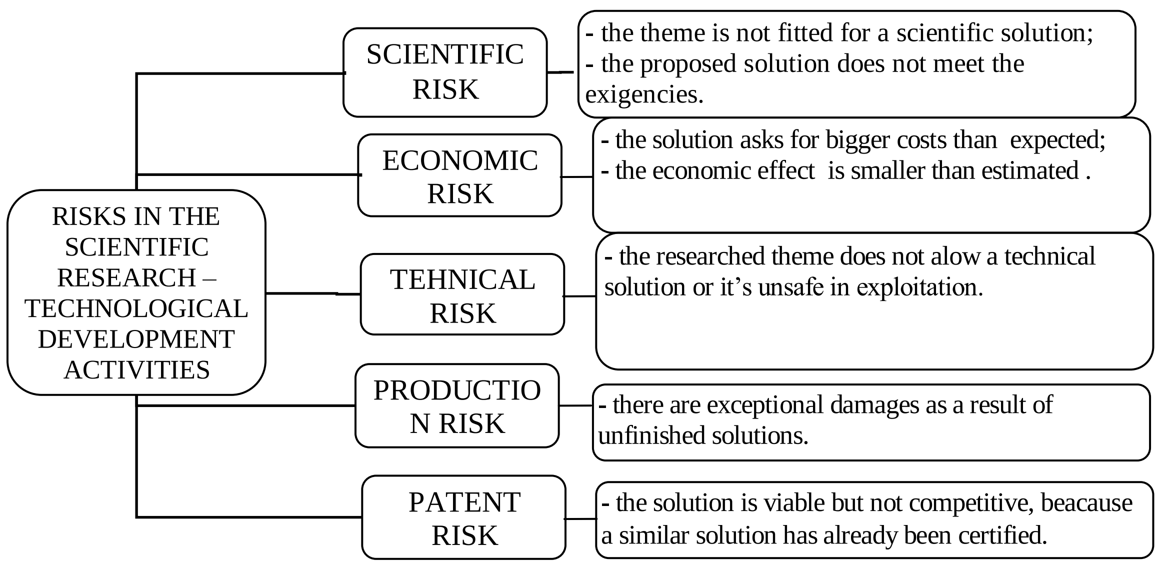

Fig. 1. *Types of risk in the scientific research – technological development activity*

(Source: Plumb I., Raţiu-Suciu I., 2003)

Specialized literature outlines the idea that, because of the intensification of the international exchange of the intellectual work products (scientific research – technological development system), the risk dimensions are conditioned by:

- the gap between the present technical level and the one in the development project, meaning that the risk becomes higher proportionally with this gap;
- the cost dynamic of the products or services obtained as a result of the application of the solutions offered by the scientific research – technological development system, meaning as lower these prices can get on the external market, as higher

the risk's dimensions (which means that there will be a slower and smaller recuperation of the expenses that were made).

- The level of technical development, of organizational conditions and the sales level of the partners who work in research and production (international cooperation) in the same field. (Plumb I., Raţiu-Suciu I., 2003)

5. Conclusions

At this time, in Romania, we can still feel the burden of the economic crisis triggered in the second half of 2008, and the government budget does not have the resources necessary for surpassing it, but, still, Romania cannot allow to lose scientific research because, nowadays, the struggle for economical and technological supremacy in which only the great powers take part, is doubled by a struggle for intellectual supremacy, in which all states take part, regardless of their size. The absence of one country leads to its disqualification, with potential dramatic effects. Furthermore, in the Law concerning the research it is mentioned that the scientific research is a national priority.

Unfortunately, the research has not been a priority during the last 20 years and the proof is the small amounts allocated to research from the government budget, and for this reason we are positioned on one of the last places in the classification of the EU states, concerning the allocations for research coming from the budget.

Nevertheless, this does not mean that all that has been done until now is to be blamed or ignored. Almost all efforts have been made for maintaining the existent system: the main work was "surviving", and the major problem was the absence of funds. A long period of time some institutions and companies have been financed simultaneously, without calculating the economic efficiency of results. There has not been an institutional restructuring nor a reevaluation of the research management system. (Florescu M. S., 2006)

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