# SEISMIC RISK CONCENTRATORS MAP BASED ON DYNAMIC STRUCTURE RESPONSE

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*Scopul lucrării este acela de a stabili un algoritm bazat pe utilizarea unui model mecanic, dinamic şi matematic pentru a crea o hartă a fluxului de concentratori cu risc seismic pentru o clădire construită. Primul pas al acestui algoritm propus de autori este legat de folosirea unui software specializat pornind de la un model al clădirii (o structură construită) care va fi şi analizat. Pe baza rezultatelor obţinute în cea de-a doua etapă putem să generăm o hartă cu zonele care trebuie evitate în cazul evacuării resurselor umane şi materiale datorită posibilităţii mari de prăbuşire a clădirii, astfel încetinind sau blocând evacuarea.*

*The goal of this paper is to establish an algorithm based on the use of a mechanical, dynamic and mathematical model in order to create a map for the seismic risk flow concentrators in a built structure. The first step of the algorithm proposed by the authors is the use of a specialised software solution starting from the model of the building that is analysed. Based on the obtained results, in the second step we can generate a map with the areas that must be avoided when evacuating people and materials due to high possibility of failure of the structure, thus slowing people down or blocking the evacuation.*

**Key words:** seismic risk, flow concentrator, dynamic structure response.

## 1. Introduction

The analysis of a structure for seismic strength follows the next fundamental aspects:

- Geometrical, physical, mechanical and mathematical modelling of the strength structure (materials, component elements, substructures, connections, etc.).
- Geological, geotechnical and dynamical modelling of the local field conditions corresponding to the construction placement [1].
- Cinematic and parametric modelling of the seismic movement in time.
- Numerical analysis estimating the instant and maximum response of the structure during analysis of the earthquake.

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## 2. Anti-seismic design in dynamic concept

The dynamic response of the structure caused by strong earthquake can be determined through three distinct methods (or variants) that are presented as it follows:

Method 1: Static-equivalent seismic force method. This method is conventional and approximate and it is included in design rules and normatives. It is a simplified method, specific to a global analysis in which the seismic ensures level is prescribed depending on the area of seismicity and the structure dynamical characteristics (own periods and dissipation capacity), as well as on a certain allowed level of ductility.

Method 2: Response seismic spectres method. It is also an approximate method that is utilised in direct design of the strength structures to earthquakes.

The method offers the possibility to separate the structure dynamic characteristics (from the seismic movement ones) defined through „response seismic spectres". This approach method is used in present in anti-seismic design of structures and can be considered an analysis instrument in preliminary design guarantying a more precisely calculus.

Method 3: Anti-seismic design in dynamic concept: The dynamic behaviour of the structures, during historical time of the seismic movement, is much more complex then the static behaviour under the action of gravity load, therefore design and anti-seismic safety needs more refined numerical analysis and structural conformity techniques [2]. Anti-seismic design concept is based on the definition and synthesise of the structure configuration (shapes, dimensions, components, connexions, etc.) according to the field movement characteristics (intensity, duration, spectral frequency-composition content, etc.), to the elastic and dynamic properties of the structure (inertial, dissipative, stiffness, ductility), to the infrastructural type (foundation) and the placement environment (field local conditions) [3]. When designing a structure (with precise destination) for a standard earthquake action, also called „designing earthquake" there are many possible variants regarding the choice of possibilities for the tridimensional structure configuration [4], [5]. The adapted structural type and used material can have a great influence on the local and assembly stiffness, attenuation capacity, possibility of moving forward the behaviour elastic limit [6]. Post-elastic incursions are very much dependant on the hysteresis properties, on the ductile behaviour of the material and structural and non-structural components as well as on the connections realisation mode that insures the mutual transfer of the deformations between the constitutive elements. Following the aspects given above, we can conclude that in order to design a strength structure against earthquakes in dynamic concept we must optimally associate the following fundamental properties which define the components and the structural units:

strength, stiffness capacity, energy dissipation and ductility capacity, ability to guarantee a seismic safety level to a construction, in the established limits. In the same time it is necessary to pay a special attention to the local placement conditions, taking into consideration the decisive influence that this can have in the design process [7]. The dynamic concept of anti-seismic design of structures, regarding an allowed safety level, is a recent concept that includes many aspects specific to seismic phenomenon [8]. When elaborating a strength project one must keep in mind the following global characteristics that define the geometric configuration and the calculus method of a structural unit: local or general inertial characteristics; elastic characteristics of the cross sections, elements, substructures and connections, expressed through stiffness or flexibility [9]; dissipative characteristics and characteristics of attenuation corresponding to the structural and non-structural components, in the elastic and post-elastic behaviour domain; ductility characteristics and inelastic behaviour characteristics of the cross sections, elements, substructures and structures from the assembly [10]. The dynamic concept, element, substructure or tridimensional structure regarding the design structures against seismic actions of high intensity, has an extremely complex character and cannot be defined with the usual saying „engineering common sense” [11]. The dynamic concept of strength structures treating (regarding as well the participation of the elements called „un-portant” or „non-structural”, from gravitational point of view, but with important dynamical function) means to study every detail and component element up to the whole structural assembly [12]. This is the reason for which we used a special numerical tool from the seismic engineering domain; the ETABS program (Integrated Building Design Software) produced by Computers and Structures Inc. Berkeley, California USA in order to complete the first step of the proposed algorithm.

## 3. Elaboration and simulation of the dynamic model of the structure

In this chapter we find necessary to present a detailed description of the features of the program, the reason being our interest to the information provided by the program that are materialised in the seismic risk concentrators map.

The elements used in the analysis process by the ETABS programme are : static and dynamic analysis for frame type structures or structural walls; automatic calculus of the stiffness centre; loads given by the gravitational force, pressure and temperature; frame type objects drawn as physical elements; digitization with finite elements for disc / dales for the horizontal diaphragms analysis; modelled wall / disc / dale as „shell” „plate” or „membrane” type element; statically and dynamical analysis corresponding to the execution phases; consideration of the plastic articulations from the axial force, flexural torque, shearing force and torsion; incremental nonlinear analysis („push-over"); structural response control by isolating the base or viscous attenuation units; elevated displacements systems analysis. The elements used for presentation by ETABS programme are: 3D graphic displays; stress diagrams for bars, walls and disc; results selection with screen displaying; table showing of the entry and exit data; graphic definition „section cut" type for stresses; „open gl viewer"; displacements and stresses showing in the „time-history" analysis; „avi" file type for „time-history"; spectral response curves for „time-history" analysis; force – displacement diagram in the nonlinear response domain; graphic representation of the plastic hinges.

The elements used for calculus in the ETABS programme are as follows: metallic frame calculus for various designing codes; armed concrete frame calculus for various designing codes; composite grinds calculus corresponding to the American, English and Canadian code; armed concrete walls calculus for American, English and Canadian codes; static and dynamic loads calculus; „section designer" mode for non-regular shape sections description.

The obtained data (reports given by ETABS) are going to be input data in order to create a seismic risk concentrators map.

The image of the structure modeled by ETABS programme is given in figure 1.

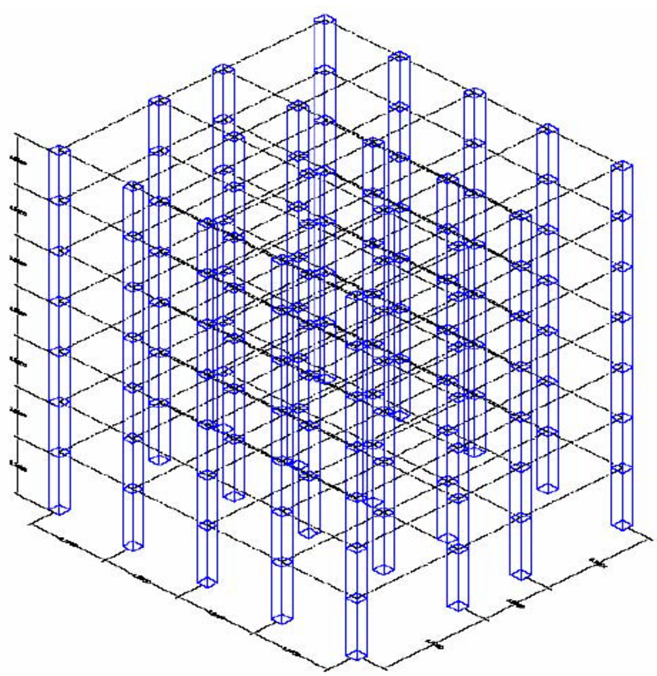

Fig. 1 Structure parameterised model of the structure modelled in ETABS programme

The most important parameters of the model given in figure 1, as they are defined in the ETABS program are:
ETABS v8.4.8 File:CLADIRE_S_P_6E Units :KN-m
M A T E R I A L P R O P E R T Y D A T A
MATERIAL MATERIAL DESIGN MATERIAL MODULUS OF POISSON'S THERMAL SHEAR
NAME TYPE TYPE DIR/PLANE ELASTICITY RATIO COEFF MODULUS STEEL Iso Steel All 199948000.00 0.3000 1.1700E-05 76903076.92 C2025 Iso Concrete All 30000000.000 0.2000 9.9000E-0612500000.000 M A T E R I A L P R O P E R T Y M A S S A N D W E I G H T MATERIAL MASS PER WEIGHT PER NAME UNIT VOL UNIT VOL STEEL 7.8271E+00 7.6820E+01 C2025 2.5000E+00 2.5000E+01 M A T E R I A L D E S I G N D A T A F O R S T E E L M A T E R I A L S MATERIAL STEEL STEEL STEEL NAME FY FU COST ($) STEEL 344737.900 448159.300 271447.20 MATERIAL DESIGN D A T A F O R C O N C R E T E M A T E R I A L S MATERIAL LIGHTWEIGHT CONCRETE REBAR REBAR LIGHTWT
NAME CONCRETE FC FY FYS REDUC FACT C2025 No 20500.000 345000.000 345000.000 N/A F R A M E S E C T I O N P R O P E R T Y D A T A MATERIAL SECTION SHAPE NAME OR NAME CONC CONC FRAME SECTION NAME NAME IN SECTION DATABASE FILE COL
BEAM F R A M E S E C T I O N P R O P E R T Y D A T A SECTION FLANGE FLANGE WEB FLANGE FLANGE FRAME SECTION NAME DEPTH WIDTH TOP THICK TOP THICK WIDTH
BOT THICK BOT SC 0.6000 0.6000 0.0000 0.0000 0.5000 0.0000 SML 0.6000 0.6000 0.0000 0.0000 0.5000 0.0000 SMF 0.6000 0.6000 0.0000 0.0000 0.5000 0.0000 SI 0.7000 0.7000 0.0000 0.0000 0.6000 0.0000 GL 0.5500 0.7500 0.1500 0.2500 0.7500 0.1500 GT1 0.6000 0.9000 0.1500 0.3000 0.7500 0.1500 GT2 0.6000 0.9000 0.1500 0.3000 0.7500 0.1500 F R A M E S E C T I O N P R O P E R T Y D A T A SECTION TORSIONAL MOMENTS OF INERTIA SHEAR AREAS FRAME SECTION NAME AREA CONSTANT I33 I22 A2 A3 SC 0.3600 0.0183 0.0108 0.0108 0.3000 0.3000 SML 0.3600 0.0183 0.0108 0.0108 0.3000 0.3000 SMF 0.3600 0.0183 0.0108 0.0108 0.3000 0.3000 SI 0.4900 0.0338 0.0200 0.0200 0.4083 0.4083 GL 0.2125 0.0028 0.0055 0.0058 0.1375 0.0938 GT1 0.2700 0.0047 0.0086 0.0101 0.1800 0.1125 GT2 0.2700 0.0047 0.0086 0.0101 0.1800 0.1125 F R A M E S E C T I O N P R O P E R T Y D A T A SECTION MODULI PLASTIC MODULI RADIUS OF GYRATION FRAME SECTION NAME S33 S22 Z33 Z22 R33 R22 SC 0.0360 0.0360 0.0540 0.0540 0.1732 0.1732 SML 0.0360 0.0360 0.0540 0.0540 0.1732 0.1732 SMF 0.0360 0.0360 0.0540 0.0540

0.1732 0.1732 SI 0.0572 0.0572 0.0858 0.0858 0.2021 0.2021 GL 0.0161 0.0155 0.0284 0.0273 0.1616 0.1651 GT1 0.0230 0.0225 0.0405 0.0405 0.1785 0.1936 GT2 0.0230 0.0225 0.0405 0.0405 0.1785 0.1936 F R A M E S E C T I O N W E I G H T S A N D M A S S E S FRAME SECTION NAME WEIGHT MASS SC 745.2000 74.5200 SML 1117.8000 111.7800 SMF 745.2000 74.5200 SI 1521.4500 152.1450 GL 2119.6875 211.9688 GT1 2395.5749 239.5575 GT2 694.5751 69.4575 C O N C R E T E C O L U M N D A T A
REINF CONFIGURATION REINF NUM BARS NUM BARS BAR FRAME SECTION NAME LONGIT LATERAL SIZE/TYPE 3DIR/2DIR
CIRCULAR COVER SC Rectangular Ties 16d/Design 5/5 N/A 0.0457 SML Rectangular Ties 16d/Design 5/5 N/A 0.0457 SMF Rectangular Ties 16d/Design 5/5 N/A 0.0457 SI Rectangular Ties 16d/Design 5/5 N/A 0.0457
C O N C R E T E B E A M D A T A TOP BOT TOP LEFT TOP RIGHT BOT LEFT BOT RIGHT FRAME SECTION NAME COVER COVER AREA AREA AREA AREA

| | | | | | | |
|---|---|---|---|---|---|---|
| GL | 0.0152 | 0.0152 | 0.000 | 0.000 | 0.000 | 0.000 |
| GT1 | 0.0152 | 0.0152 | 0.000 | 0.000 | 0.000 | 0.000 |
| GT2 | 0.0152 | 0.0152 | 0.000 | 0.000 | 0.000 | 0.000 |

S H E L L S E C T I O N P R O P E R T Y D A T A SHELL MATERIAL SHELL LOAD DIST MEMBRANE BENDING TOTAL SECTION NAME TYPE ONE WAY THICK THICK WEIGHT MASS PLACA C2025 Membrane No 0.1500 0.1500 6615.0000 661.5000 S T A T I C L O A D C A S E S STATIC CASE AUTO LAT SELF WT CASE TYPE LOAD MULTIPLIER GP DEAD N/A 1.0000 ATIC DEAD N/A 0.0000
HZ DEAD N/A 0.0000
INCHIDERE DEAD N/A 0.0000
PARDOSEALA DEAD N/A 0.0000
COMPARTIM DEAD N/A 0.0000
UTILA DEAD N/A 0.0000
ZAPADA DEAD N/A 0.0000
SX QUAKE USER_COEFF 0.0000
SY QUAKE USER_COEFF 0.0000

Based on this parametric model the ETABS program will generate reports regarding the moments, shearing and axial forces diagrams and, separately for the earthquake (on both directions X and Y).

An example of this type of report is given in figure 2.

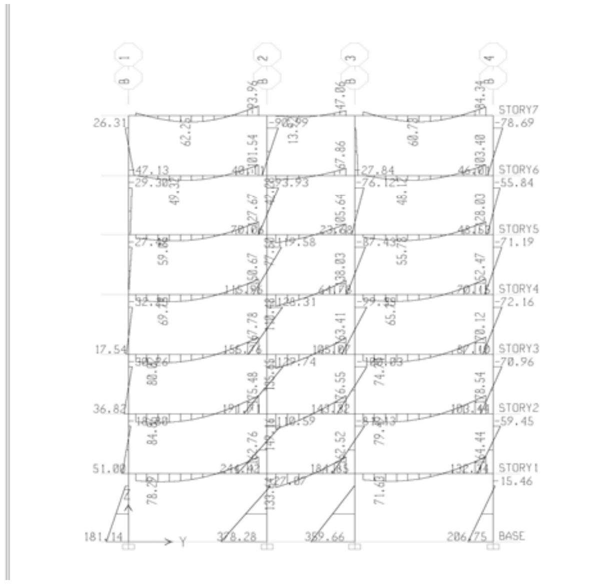


Fig. 2 Generated report for a parametric model of the build structure using ETABS program

**4. Digital map for seismic risk concentrators**

Using the reports generated by the ETABS program we were able to create a digital map with seismic risk concentrators. Some relevant aspects of the model for which this map was build are given below.

DISPLACEMENTS AT DIAPHRAGM CENTER OF MASS STORY DIAPHRAGM LOAD UX UY RZ STORY7 D1 SX 0.0204 0.0000 -0.00020 STORY6 D1 SX 0.0191 0.0000 -0.00019 STORY5 D1 SX 0.0170 0.0000 -0.00017 STORY4 D1 SX 0.0141 0.0000 -0.00014 STORY3 D1 SX 0.0105 0.0000 -0.00011 STORY2 D1 SX 0.0065 0.0000 -0.00007 STORY1 D1 SX 0.0027 0.0000 -0.00003 BASE D1 SX 0.0000 0.0000 0.00000 STORY7 D1 SY 0.0000 0.0173 -0.00023 STORY6 D1 SY 0.0000 0.0162 -0.00021 STORY5 D1 SY 0.0000 0.0145 -0.00019 STORY4 D1 SY 0.0000 0.0121 -0.00016 STORY3 D1 SY 0.0000 0.0091 -0.00012 STORY2 D1 SY 0.0000 0.0057 -0.00008 STORY1 D1 SY 0.0000 0.0024 -0.00003 BASE D1 SY 0.0000 0.0000 0.00000 STORY MAXIMUM AND AVERAGE LATERAL DISPLACEMENTS STORY LOAD DIR MAXIMUM AVERAGE RATIO STORY7 SX X 0.0219 0.0204 1.075 STORY6 SX X 0.0205 0.0191 1.075 STORY5 SX X 0.0183 0.0170 1.076 STORY4 SX X 0.0152 0.0141 1.077 STORY3 SX X 0.0113 0.0105 1.078 STORY2 SX X 0.0071 0.0065 1.080 STORY1 SX X 0.0029 0.0027 1.083 STORY7 SY Y 0.0192 0.0173 1.110 STORY6 SY Y 0.0181

0.0162 1.111 STORY5 SY Y 0.0161 0.0145 1.112 STORY4 SY Y 0.0134 0.0121 1.112 STORY3 SY Y 0.0101 0.0091 1.113 STORY2 SY Y 0.0064 0.0057 1.115 STORY1 SY Y 0.0027 0.0024 1.117

## 5. Conclusions

The numerical models for the flow concentrators' map can be inserted in a united multi-expert type computer field system that allows data centralization from more that one build structures and evacuation flows simulation for the whole build assembly, neighbourhood, sector, etc. We consider that a special interest should be given to the researches regarding the build structures behaviour modelling with the purpose of industrial activities running.

Based on the communication between human and material flows and management software for discrete values material flows, the material flow evacuation will consider a structural risk concentrators map that is different then the one with buildings or offices constructions due to the working point, stochastic systems, transfer and transport systems influence.

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