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Development of a teaching tool for the study of skew bending for general concrete cross-sections

Desenvolvimento de uma ferramenta didática para o estudo da flexão composta oblíqua em seções quaisquer de concreto armado

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Abstract

Bearing in mind the experience of teachers and researchers from Brazil as well in foreign countries searching for new and better teaching methods for engineering education, it appears that the use of interactive multimedia is a promising approach, with a lot of opportunities for application in subjects for graduation. In that context, this work deals with the development of a multimedia tool to support the teaching of skew bending in reinforced concrete, presenting its features, the structure of the code and examples of application. For the construction of the multimedia tool, the applet "Verificação de seções quaisquer de concreto armado sob flexão composta oblíqua", was used as a programming language called JavaTM and the development environment, NetBeans 5.5.1. The applet treated in this article is available on the Internet at http://www.lmc.ep.usp.br/pesquisas/TecEdu/ .

Keywords: *Applets, Engineering education, Skew Bending*

Resumo

Tendo em vista a experiência de professores e pesquisadores do Brasil e do exterior no contexto da busca de novos e melhores métodos didáticos para ensino de Engenharia, constata-se que o uso de recursos multimídia interativa constitui uma abordagem promissora, com amplas possibilidades de aplicação em disciplinas de graduação. Nesse contexto, o presente trabalho trata do desenvolvimento de uma ferramenta multimídia de apoio ao ensino da flexão composta oblíqua no concreto armado, apresentando as suas funcionalidades, a estrutura do código e exemplos de aplicação. Para a construção da ferramenta, o applet "Verificação de seções quaisquer de concreto armado sob flexão composta oblíqua", foi utilizada a linguagem de programação JavaTM e o ambiente de desenvolvimento NetBeans 5.5.1. O applet tratado neste artigo está disponível na Internet no endereço http://www.lmc.ep.usp.br/pesquisas/TecEdu/.

Palavras-chave: Applets*, Ensino de engenharia, Flexão composta oblíqua.*

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1. Introduction

The evolution of information technology and communication as well as the emergence of new methodologies and teaching techniques geared to the student, promoted a paradigm shift in teaching context, leading to the emergence of e-learning and multimedia tools in the service of education.

There arises from this new reality, the motivation to monitor the current progress and put in the service of teaching the latest technological resources available, which, if used correctly, in quantity and quality, arguably provide significant results in terms of motivation and student learning.

Thus, it is essential the teacher knows how to use these new tools, as it is essential that the developer be able to plan and build the resources so that enhances the activity of teaching and learning. Among the tools most used by multimedia professionals in education, are the applets.

The applets are the programs written in Java™ that are sent by a computer-server over the Internet and are installed on the client computer from parts of a page on the World Wide Web. The Applet mentioned in this article is available in the Internet at http://www.lmc.ep.usp.br/pesquisas/TecEdu/.

The development tools needed to build the applet in this study were created with the programming language Java™ development environment NetBeans ®. Over the next few items, you will see the applet "Verificação de seções quaisquer de concreto armado sob flexão composta oblíqua", approaching aspects as the methodology used in its development and programming details, and examples of application of the applet.

2. The java language

Java is a high-level language programming developed by Sun Microsystems, that was initially called Oak, and was designed for por-

table devices. But Oak was not successful, then the Sun in 1995, changed the name to Java™ and modified a bit the language to adapt with the growth of the World Wide Web.

Java™ is an object-oriented language like C++, but simplified to eliminate language features that cause common programming errors.

The language files are compiled into a format called bytecode, which can be executed by a interpreter Java™, known as Java Virtual Machine (JVM).

The compiled code can run on most computers, since Java™ can be interpreted and implemented in several operating systems including UNIX, Macintosh OS and Windows. Java™ is a language for general purpose programming with a series of characteristics that make the language well suited for use on the World Wide Web.

With Java it is possible to create an applet, which is a software running under another program. It can be downloaded from a web server and run on a computer using a browser that supports Java™, as Mozilla Firefox or Microsoft Internet Explorer.

In short, Java language was designed to meet the following requirements:

- Object-oriented programming;
- Portability - platform independence;
- Resources Network - has extensive library of routines that facilitate cooperation protocols with TCP / IP;
- Security.

# 3. The *Applet* "Verificação de Seções Quaisquer de Concreto Armado Sob Flexão Composta Oblíqua"

3.1 Graphical User Interface

The graphical interface was created in a simple way for the user not experience difficulties with the program (Figure 1).

In the JPanel "Esforços Solicitantes", the user enters the values of axial force and the bending moments acting in the studying cross-

Figure 1 – Graphical User Interface program

Figure 2 – Message stating that the value entered is outside the allowed
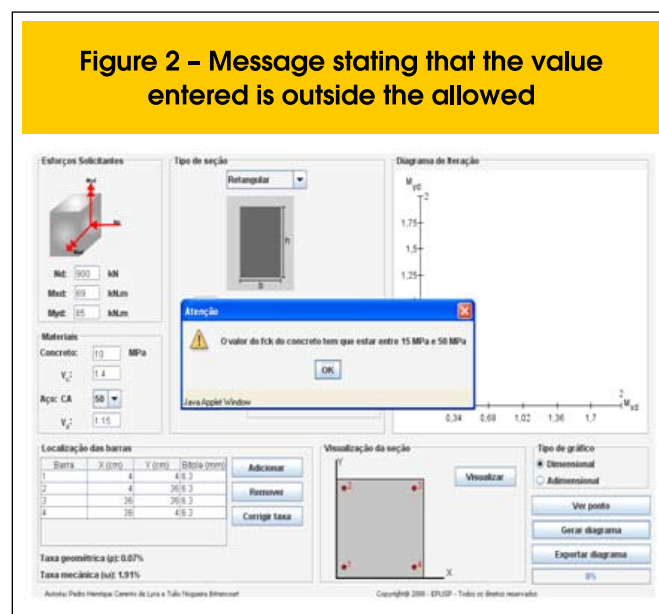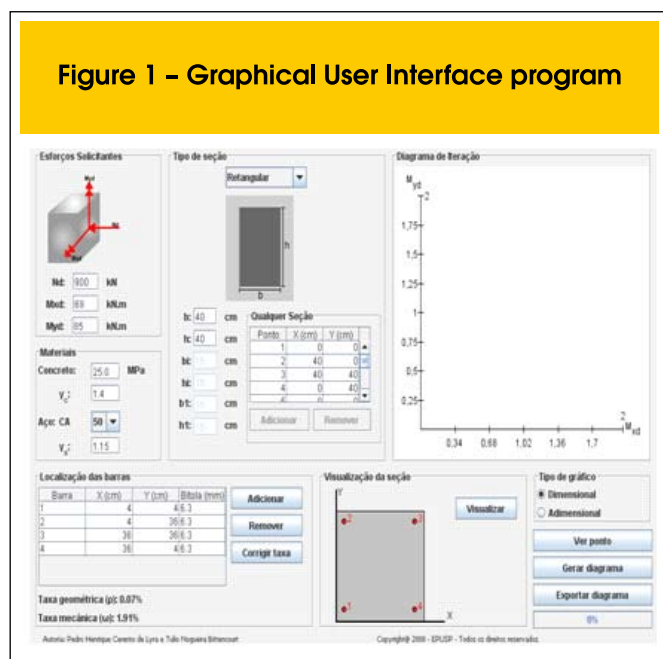
Figure 3 – Environment for selection and placement of reinforcement bar
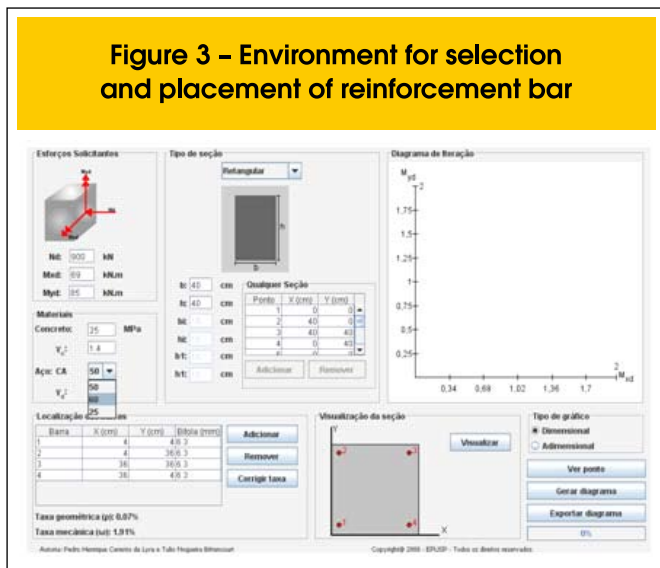
Figure 5 – Menu featuring the cross sections available
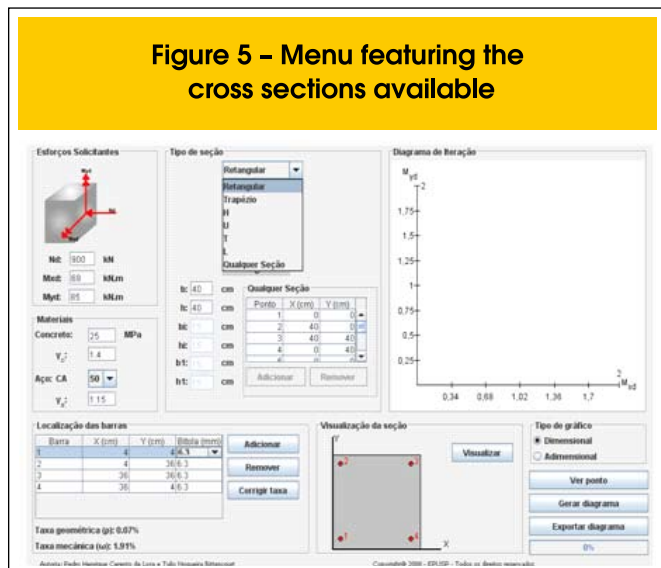
section, and there is a figure to guide the user on sign conventions used by the program.

User can choose the resistance of concrete typing the value in the TextField located in the JPanel "Materais", noting that this value should be between 15 MPa and 50 MPa. If the value entered is outside those limits, the program will provide a warning message and will not be drawn the diagram (Figure 2).

In the case of choosing the type of steel, this is made through a JComboBox component located in the JPanel "Materiais" shown in Figure 3.

In the JPanel "Localização das barras", the user must enter the number of bars you want in the section, as well as necessary gauges of each bar (Figure 4). User has the option of working with cross-sections pre-defined and need only define the dimensions,

or create various geometries; these choices are available in the JPanel "Tipo de Seção" (Figure 5).

After the user enters all data in the program just need to click on the button "Gerar Diagrama" and he obtained the diagram shown in Figure 6. User has available the choice of iteration diagram dimensional or adimensional, in the JPanel "Tipo de Gráfico".

As can be seen, the applet provides the mechanical and geometric rates of reinforcement according to the cross section as defined by the user.

In the JPanel "Diagrama de Iteração" is shown the diagram generated for a section, there is a point of particular importance, red, which represents the corresponding position due to the moments acting on the section. If the red dot is inside or at the border of the diagram, as shown in Figures 6 and 8, the section resists the internal forces, but if the point is outside the closed line that defines the diagram, as shown in Figure 7, the section does not resist the internal forces.

Figure 4 – Menu for the definition of the gauge of a selected reinforcement bar
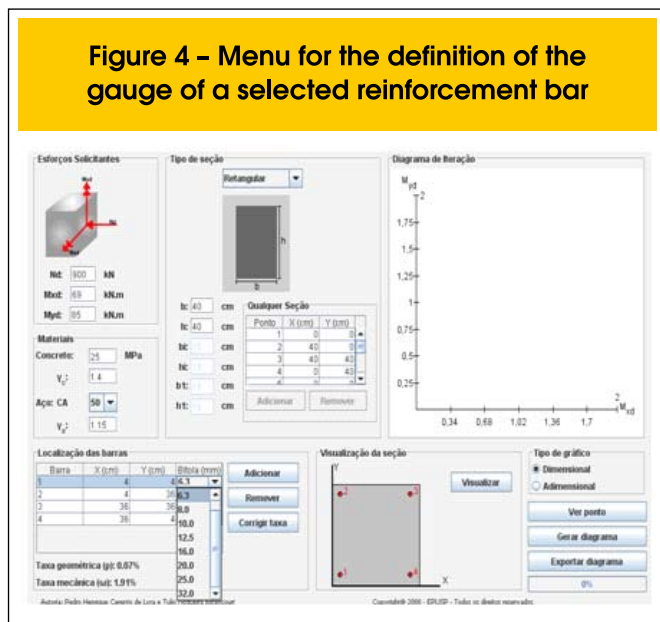
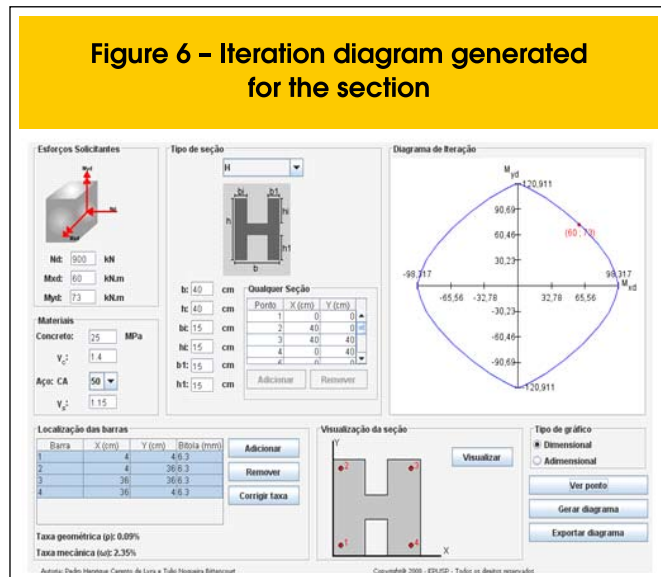**Figure 6 – Iteration diagram generated for the section**

Tabela 1 – Programming structure of the applet developed		
Package	**Class**	**What does this class do?**
Aço	Aço	Abstract class that contains all the methods that must be implemented by its child classes (area of the gauge, stress, strain and modulus of elasticity). This way you can generate different stress-strain curves for steel.
	AcoNBR6118	Area of steel adopted by NBR6118: 2003, also provides the relation stress-strain of the steel.
	Barra	This class defines the geometric parameters of the reinforcement bars
Domínios	Domínios	Interface that determines which functions should be implemented by a class that implements (DominiosNBR6118).
	Dominios NBR 6118	Implementation of the regions for NBR6118: 2003.
Shape	H	Class represents geometrically a H cross-section of the concrete.
	L	Class represents geometrically a L cross-section of the concrete.
	Qualquer	Class represents geometrically any cross-section of the concrete.
	Retângulo	Class represents geometrically a rectangular cross-section of the concrete.
	Seção	Class represents a cross-section of reinforcement concrete. It performs some calculations necessary to validate the cross-section.
	Shape	Class represents geometrically a cross-section of the concrete.
	T	Class represents geometrically a T cross-section of the concrete.
	Trapézio	Class represents geometrically a trapezoidal cross-section of the concrete.
	U	Class represents geometrically a U cross-section of the concrete.
Concreto	Concreto	Abstract class represents the concrete. This class has a method that returns a given strain deformation that must be implemented by child classes, allowing the use of different stress-strain curves by the program. This class also contains a method that, given the compression polygon of any cross-section, performs the numerical integration of resistant internal forces.
	ConcretoNBR6118	Implementation of the parabola-rectangle curve of NBR6118: 2003.
Diagrama	DiagramaFCO	Thread class generates the iteration diagram.
	Gráfico	Plot the graph of the iteration diagram dimensional and adimension in the JPanel.
	Ponto	Point is a class that stores the coordinates of a point. This class also has methods that these coordinates are transformed, so that they can translate and rotate coordinate systems.
	findBx	This class covers all regions of deformation seeking a depth of neutral axis to balance the normal stresses are very strong applicants.
Ide	FCO	Class responsible for creating the applet
	NovoJDialog	Class creates the dialog box to export the data from the iteration diagram.
	NovoJPanel	Class that generates the graphical interface of the program.
	Secao_transversal	Class responsible for showing the cross-section chosen by the user in the GUI

Figure 7 – The use of this section does not resist the internal forces
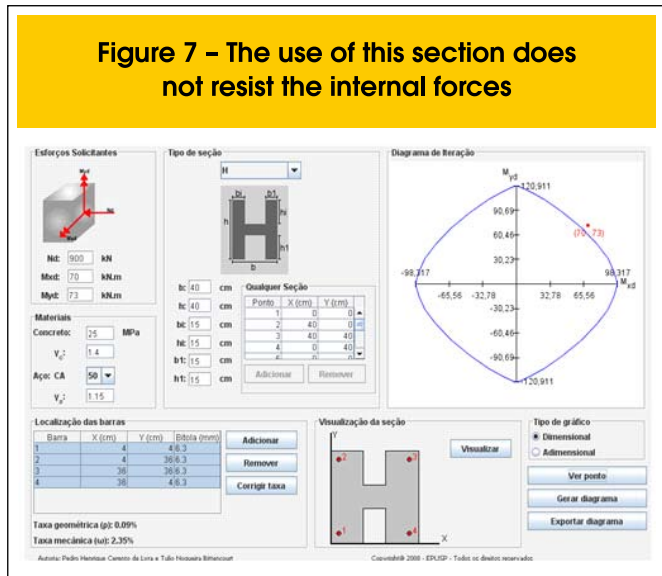
3.2 Structure of the applet programming

Table 1 lists the packages and classes used in the applet and a summary of the functionality of each class. For more information about the code, you should visit the http://www.lem.ep.usp.br/membros/pedro/index.htm, which contains all the code documented by the programs Doxygen and Javadoc.

4.   Using the applet

The results obtained by the program were compared with the examples solved in Langendonck (1977) for the section with the diamond and cross, with excellent results.

Note that the bars location table doesn't have the value of the gauge, but the value of the area of steel used in the examples. This change was necessary because of unusual areas of steel used in the examples, the user doesn't have that option.

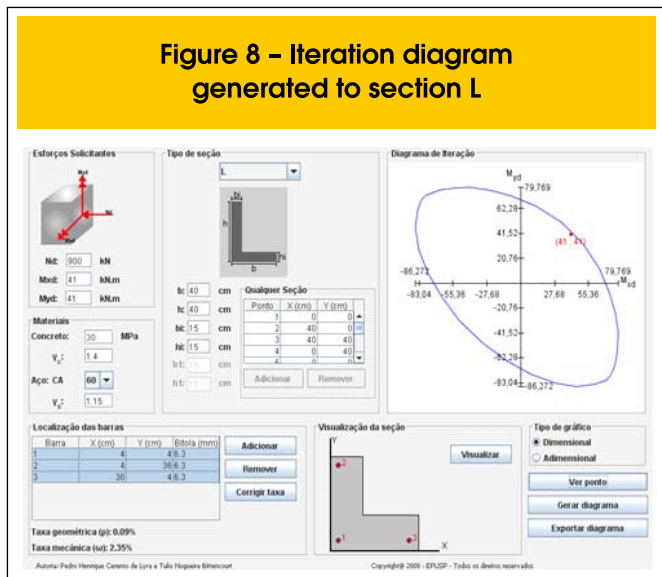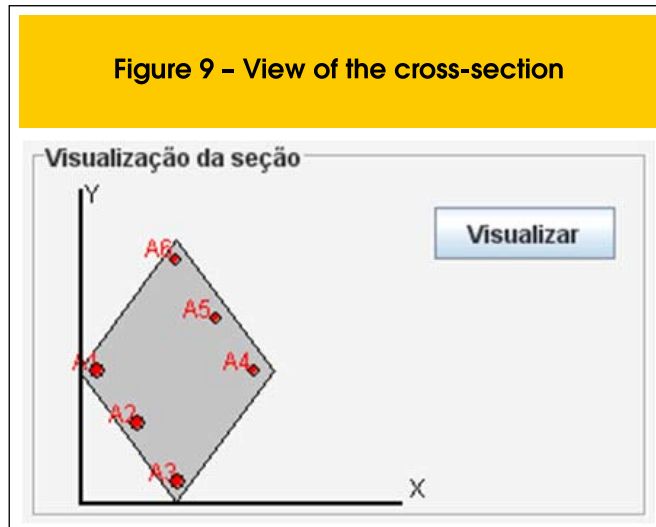**Figure 8 – Iteration diagram generated to section L**

Figure 9 – View of the cross-section

Example 1:
The section with diamond-shaped figure is shown below with the area of 2400 cm² and the diagonal of 80 cm and 60 cm under the effect of axial force N_d = 66 tf or 660 kN applied with eccentricity generates the moment M_{xd} = 211,2 kN.m and M_{yd} = 198 kN.m. The steel is CA-25 and the concrete is f_{cd} = 125 kgf/cm² (f_{ck} = 17,5 MPa).
Exemplo 2:
Cross-shaped section, shown in the figure 13, subjected to only bending moments, ie, N_d = 0, with bending moments M_{xd} = 249 kN.m and M_{yd} = 144 kN.m. The concrete is f_{cd} = 120 kgf/cm² (f_{ck} = 16,8 MPa) and steel CA-25.

5.   Conclusions

It was developed a robust and simple teaching tool for teaching of skew bending, remembering that can be used for general concrete cross-section.

The experiences of the use of applets in the classroom demonstrated that by the use of this tool the teacher and the student have the potential to stimulate students to use study material for further deepening the understanding of physical phenomena and theoretical concepts concerning the subject matter.

In this sense it is expected that this applet, which has been suc-

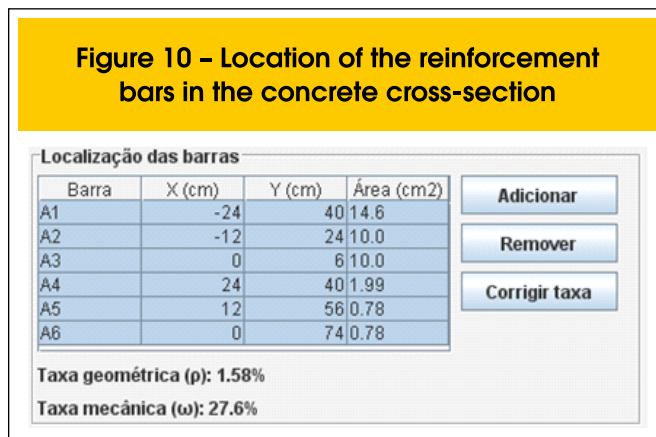**Figure 10 – Location of the reinforcement bars in the concrete cross-section**

Figure 11 – Internal forces and types of materials

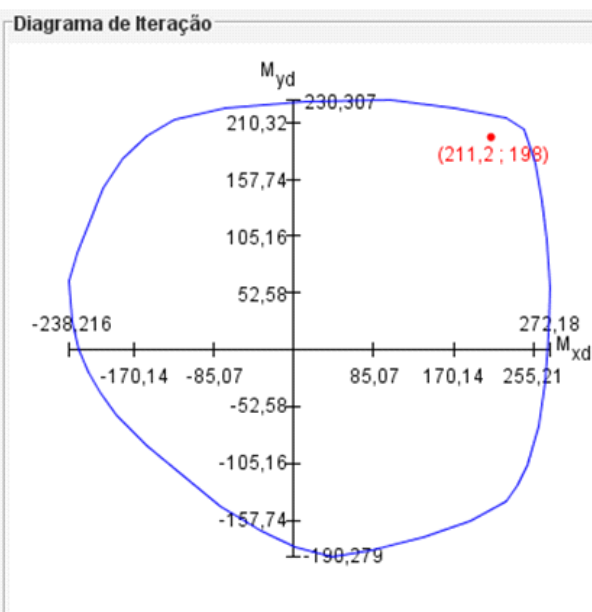## Figure 12 – Iteration diagram to the rhombic cross-section

Figure 13 – Cross-section cruciform

cessfully used in courses for undergraduate Civil Engineering from University of Sao Paulo, it´s contributes to the study and improvement of students, whether in the classroom seats or either outside the university from the Internet.

6. References

[01] ASSIS, W. S., BITTENCOURT, T. N., Desenvolvimento de uma ferramenta didática para o estudo de diagramas de interação normal-momento em colunas de concreto, Revista Engenharia Civil – Universidade do Minho, Vol. 22, pp.49-58, Janeiro 2005.

[02] ASSIS, W. S., BITTENCOURT, T. N., NORONHA, M.A.M, Desenvolvimento de Recursos Multimídia para o Ensino de Estruturas de Concreto. Revista IBRACON, vol. 32, pp.41-51, 2003.

[03] Braga, W. Uso de applets Java no ensino de engenharia: In: 28º Congresso Brasileiro de Ensino de Engenharia, XXVIII COBENGE. Ouro Preto, 2000.

[04] LANGENDONCK, Telemaco Van. Flexão composta oblíqua no concreto armado. São Paulo: EESC – USP, 1977.

[05] MEDEIROS, Gustavo Assis. Programa para Análise e Dimensionamento da Área de Armadura de Seções

Figure 14 – Location of the reinforcement bars in the cross-section

de Concreto Armado Submetidas a Flexão Oblíqua Composta, Relatório Final de Trabalho de Graduação, Instituto Tecnológico de Aeronáutica, São José dos Campos, 2004.

[06]   SANTOS, LAURO MODESTO. Sub-rotinas Básicas do Dimensionamento de Concreto Armado, São Paulo, Thot, 1994.

[07]   SANTOS, LAURO MODESTO. Calculo de concreto armado Volume 2. 2ª Edição, São Paulo, Lms, 1983.

[08]   SHEPHERDSON, E. Teaching concepts utilizing active learning computer enviroments. Tese de doutorado, 159p – Department of Civil and Environmental Engineering, Massachusetts Institute of Technology. Massachusetts, 2001.

[09]   SMANIOTTO, ALBERTO. Dimensionamento e Detalhamento Automático de Pilares Retangulares Submetidos à Flexão Composta Oblíqua. Dissertação de mestrado, Universidade Federal de Santa Catarina. Florianópolis, 2005.

Figure 15 – Internal forces and type of materials

Figure 16 – Iteration Diagram cruciform cross-section