

# Analysis of stress - strain State of the Local Bearing area caused by a Prestressed Cable Anchor in Reinforced Concrete beams according to the Nonlinear Model

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**Abstract**— The paper presents the results of stress and strain state of the local bearing area caused by a prestressed cable anchor in reinforced concrete beams. Ansys software was used to model and analyze the structure. The analysis process was carried out in 3 types: linear elastic analysis, nonlinear elastic analysis, and nonlinear analysis considering the destruction of concrete. The results of the analyses were also compared with each other.

**Keywords**— Prestressed, reinforced concrete beams, nonlinear analysis, crack.

## I. INTRODUCTION

The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

The reinforced concrete structures have been used very popular in construction and transportation works. The reasonable design for reinforced concrete components (RC) is essential to ensure the economic and technical requirements for the works [1],[2]. To achieve that, design engineers need to analyze and evaluate the behavior of load-bearing structural components [3]. According to the currently popular methods, the structural analysis is usually divided into two cases: general analysis and local analysis (or detailed analysis). The general analysis examines the overall working of the structural system with the concern of interaction behavior between structural components together. In contrast, a local analysis focused on the behavior of some small areas considered to be disadvantageous in the structure for the purpose of evaluating results or instructing to design or find solutions to limit or overcome the disadvantage of the structural parts. When analyzing the overall demand in the transport sector, there are many assumptions used to simplify and thereby reduce the amount and time of calculation. Therefore, the general analysis has been done quite completely and comprehensively in current designs. Meanwhile, the analysis and design of structures for local bearing areas faces many difficulties, especially for reinforced concrete structures although it is a very important step that affects

the safety of construction parts. According to statistics of many countries around the world, damage in reinforced concrete structures usually starts from local bearing areas, connecting areas, etc [4],[5]. So, local analysis is based on adequate and consistent consideration in suitable areas in concrete structures is a great concern today. For this purpose, the study focused on solving the problem of analyzing and calculating the local bearing area caused by a prestressed cable anchor in concrete beams according to the nonlinear model.

## II. STRUCTURE MODELING

Consider the local bearing area caused by a prestressed cable anchor in reinforced concrete beams under the effect of prestressing cable load as shown in Figure 1. Local bearing area (anchor head area) includes a prestressed cable, anchor, concrete reinforced area.

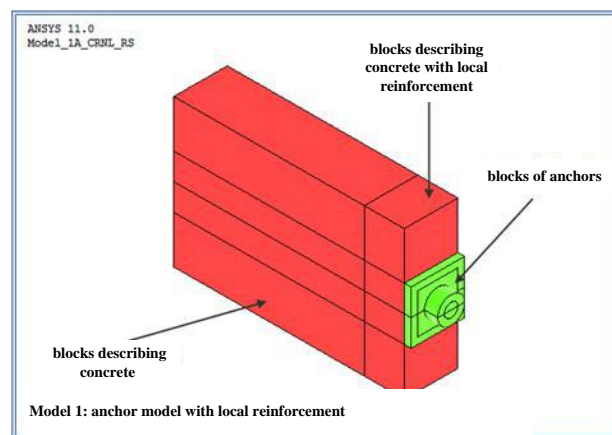


Fig.1: Geometric model

### III. TYPES OF ELEMENTS USED IN THE MODEL

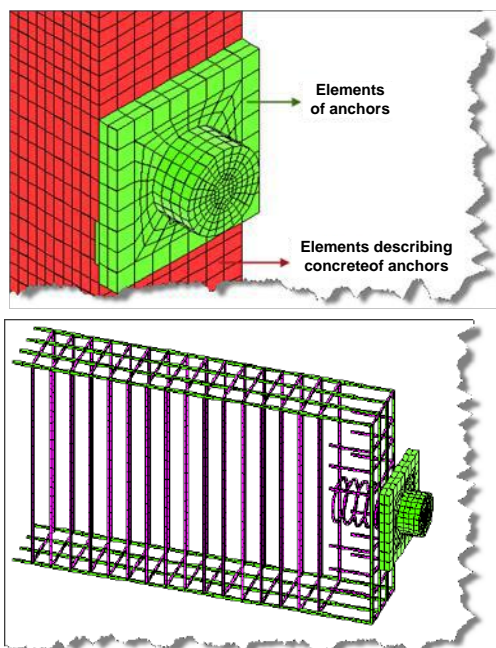


Fig.2: Elements describing concrete, anchor, reinforcement

Types of elements used in the model.

Types of elements	Purpose
Solid65	For concrete elements
Solid45	For block elements that describe anchors
Link8	For reinforcing elements

### IV. LINKS AND LOADS

**Links:** nodes at the end of the anchor area will be assigned links to control the displacements in three directions.

**Loads:** the load of the prestressed cable is transferred to the concentrated load at the anchor nodes. According to the given data, the load is divided into 5 levels and organized according to 5 data files of the corresponding load file.

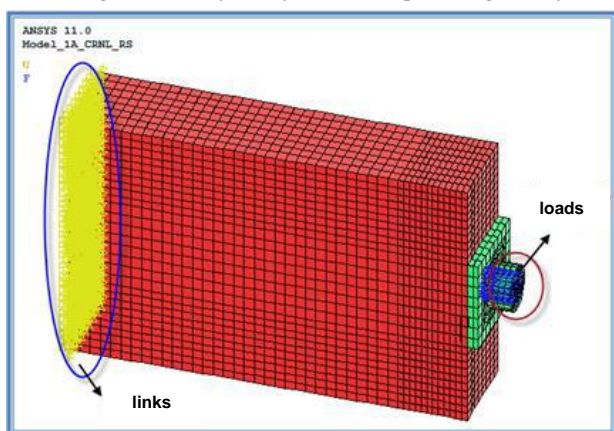


Fig.3: Load and link

### V. USING ANSYS IN MODELING AND ANALYZING LOCAL BEARING AREAS IN REINFORCED CONCRETE STRUCTURES

After the finite element model of the structure is established, the structural analysis will be performed. This work includes:

- Building element equations (element stiffness matrix, element load vector);
- Assembling the elements based on compatible models to create the structure stiffness matrix;
- Set up general equations;
- Solve general equations;
- Calculate the necessary results from the solutions of the general equation.

The form of general equations:

$$[K]\{u\} = \{P\}$$

Where:  $[K]$  is the structure stiffness matrix;  $\{u\}$  are the system node displacements;  $\{P\}$  - the general load vector.

In the case of structural behavior in linear elastic state, element stiffness matrices are constant and therefore  $[K]$  is also constant. Therefore, just one step of solving the general equation is needed to find the node displacement vector  $\{u\}$ . However, the behavior of concrete materials is nonlinear, the stiffness of the material depends on the deformation itself and thus the matrix  $[K]$  will change according to the displacement vector  $\{u\}$ . Then the general equation system will become a nonlinear system of displacement vector  $\{u\}$ . the Newton - Raphson iteration method was used to solve the nonlinear equations.

### VI. NUMERICAL RESULTS AND DISCUSSION

#### 6.1. Input data

##### Geometric data

The anchor head area of the prestressed cable is shown as the figure 4. Each prestressed steel bundle contains 14 strands of 13 mm diameter (1/2 in).

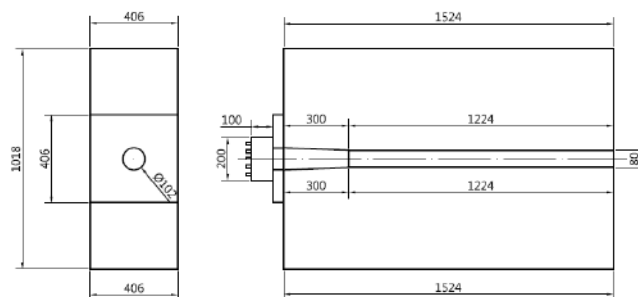


Fig.4: The general layout of the cable anchorage area

**Material**  
 Reinforcement: using steel with elastic modulus  $E = 2.1 \cdot 10^{11} \text{ N/m}^2$ , flow intensity  $f_y = 4.14 \cdot 10^8 \text{ N/m}^2$ , Poisson's coefficient  $\mu = 0.3$ .

Anchor: using steel with elastic modulus  $E = 2.1 \cdot 10^{11}$  N/m<sup>2</sup>, flow intensity  $f_y = 4.14 \cdot 10^8$  N/m<sup>2</sup>, Poisson's coefficient  $\mu = 0.3$ .

Cable: using steel with low self-slackness and maximum strength  $f_u = 1860$  MPa.

Concrete: has an initial elastic module  $E = 3.10^{10}$  N/m<sup>2</sup>, compressive strength at the time of pullin  $f_c = 34.5$  MPa  $= 3.45 \cdot 10^7$  N/m<sup>2</sup>, tensile strength  $f_{cr} = 0.95$  MPa  $= 9.5 \cdot 10^5$  N/m<sup>2</sup>, Poisson's coefficient  $\mu = 0.2$ .

Strain-stress curve of concrete with specific data is presented as table and figure below:

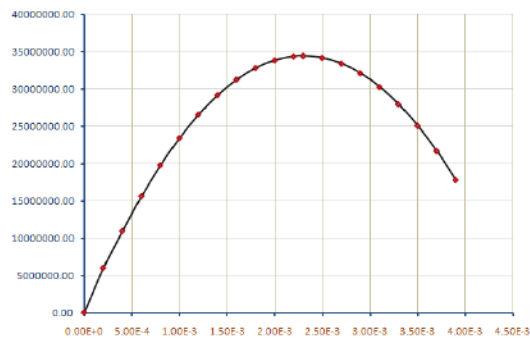


Fig.6: Stress - strain curve of concrete

## 6.2. Analysis results

Comparison between linear elastic analysis, elastic nonlinear analysis and cracked nonlinear analysis.

**Stress distribution:** When the load is low, the stress distribution is relatively similar. With a higher load, when the concrete is cracked, the stress distribution in the cracked nonlinear analysis is different from the results of the two remaining analyzes.

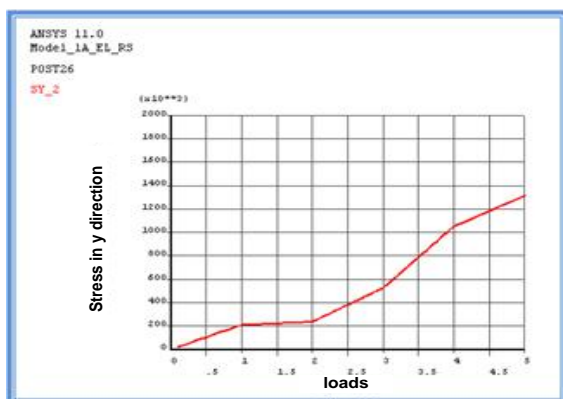


Fig.8: Stress in the Y-direction when linear elastic analysis (node 13334)

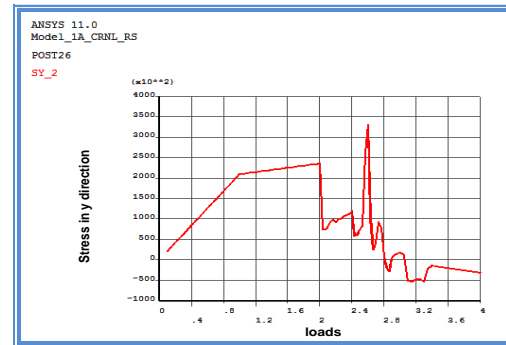


Fig.9: Stress in Y- direction with cracked nonlinear analysis (node 13334)

**Strain distribution:** Similar to stress distribution: in low load stage, strain distribution of nonlinear crack analysis is like elastic analysis; but when the load level increases, the difference in the two analysis results is clearly.

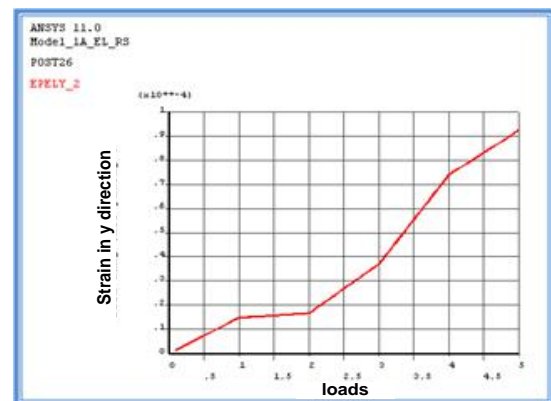


Fig.10: Strain in Y- direction with linear elastic analysis (node 13334)

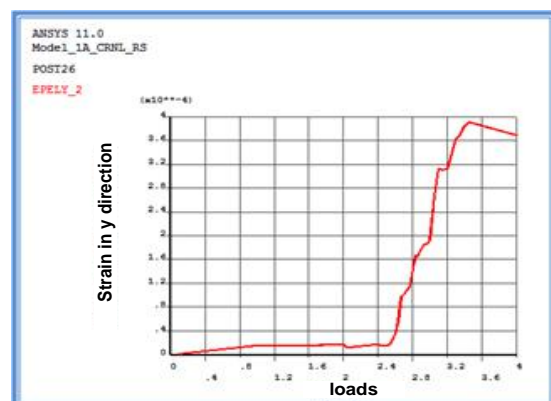


Fig.11: strain in the Y direction with cracked nonlinear analysis (node 13334)

**Cracking formation in stages:** The first crack appears at load level 1 - step 7 load at the area behind the anchor. After that, the number of cracks increases gradually in this area according to the loading steps.

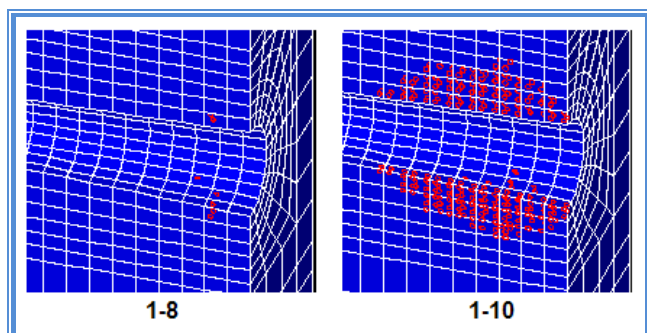


Fig.12: Cracking development in phase 1-8 and 1-10

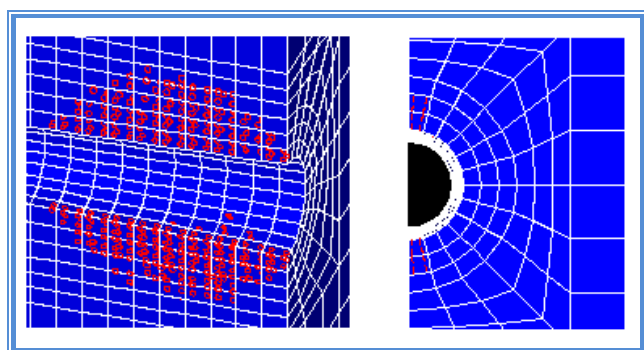


Fig.13: Cracks at phase 2-10

As the load continues to increase, cracks spread to the breaking zone and start appearing on the outside of the concrete.

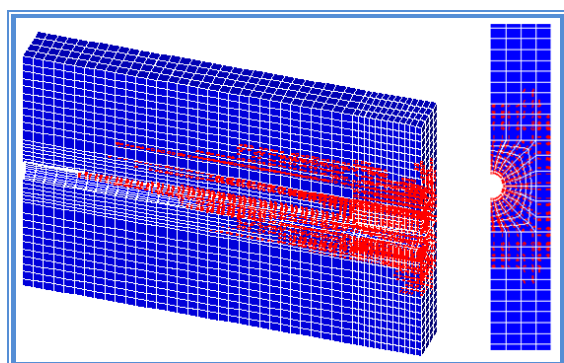


Fig.14: Development of sprung cracks at phase 3-30

Differences in stress and strain distribution in each type of analysis show: to analyze the anchor area with the cable tension load to  $0.75f_u$ , it cannot be based on elastic analysis and must consider the effect of local vandalism in concrete. Investigation of crack formation according to the stages shows: Splitting cracks will spread to the concrete surface at the adjacent area between the overall and local areas. Cracking damage has occurred since the small load. The earliest cracks occur in the concrete area behind the anchor and around the genotype. The arrangement of twisted steel to control concrete must be calculated on the basis of these cracks.

## VII. CONCLUSIONS

At the local bearing areas, the stress state is usually the multi-axial stress state and there is a large and sudden change in distribution. There, concentrated stress is very large while concrete is a material that only works linearly when stress is small (concrete begins to work nonlinearly at stresses of about 40% intensity). In addition, concrete is an anisotropic material (totally different compressive and tensile behavior) and cracks in the structure can appear at the time of fabrication as well as when the load is first started. Another difficulty is that reinforced concrete is a composite material consisting of two components, concrete and reinforced with work. In the general analysis, with simple stress state and small stress values, due to the co-deformation of concrete and reinforcement as well as limiting cracking problems, it can be simplified by considering reinforced concrete is a homogeneous material (through the calculation between concrete and reinforcement). For locally stressed areas, due to the complex stress state as well as the great concentration stress, the deformation between concrete and reinforcement is not guaranteed, especially when the concrete has been cracked. So describing the work of concrete and reinforcement is not easy. In this study, the authors used nonlinear theory and finite element method with the support of Ansys software to fully and comprehensively consider the behavior of the local bearing area in phases with different load segments of post-tensioning cable anchors. The results are the initial foundation for the authors to develop other local bearing areas in reinforced concrete structures such as the position of the bearing of the abutment or local bearing area of other structural materials such as composite materials.

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