Modelling of Work of Cut and Stretchy Sheet in Span Beam Structures with the Mixed Reinforcement

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Abstract. The constant growth of the intensity and volumes of automobile transportation causes the necessity of the increasing the requirements to the serviceability of transport facilities. The issue of the serviceability and safe operation of the existing highway or pedestrian bridges, which were built many years ago, is always relevant. Therefore, there is a choice: either to restore and strengthen the existing facilities or to replace them completely. It is expedient and efficient to use a steel cut and stretchy sheet in the form of the external ribbon reinforcement at the strengthening of the reinforced concrete span bridge structures. In the future, the steel cut and stretchy sheet is properly attached to the surface of the structure and the filling of the sheet cell is done by the layer of the cement and sandy solution (the process of concrete spraying) or protected by a concrete layer for the prevention of the sheet corrosion. Such a cut and stretchy sheet can be effectively used in new structural elements at new construction as a working longitudinal or transversal reinforcement. An effective version of the use of the cut and stretchy sheet is possible for the strengthening not only bending structures but also compressed and compressed out of center reinforced concrete and stone ones. Thus, the issue of the research and modeling of the work of the steel cut and stretchy sheet in the array of concrete under the linear stressed state conditions is of vital importance. The article presents the results of the experimental and theoretical research of the work of the steel cut and stretchy sheet under load; provided the physical model of such a process; substantiates the effectiveness of its use and the placement in span beam bridge structures.

1. Introduction
The constant growth of the intensity and volumes of automobile transportation causes the necessity of the increasing the requirements to the serviceability of transport facilities. The issue of the serviceability and safe operation of the existing highway or pedestrian bridges, which were built many years ago, is always relevant. Therefore, there is a choice: either to restore and strengthen the existing facilities or to replace them completely. It is expedient and efficient to use a steel cut and stretchy sheet in the form of the external ribbon reinforcement at the strengthening of the reinforced concrete span bridge structures [1]. In the future, the steel cut and stretchy sheet is properly attached to the surface of the structure and the filling of the sheet cell is done by the layer of the cement and sandy solution (the process of concrete spraying) or protected by a concrete layer for the prevention of the sheet corrosion. Such a cut and
stretchy sheet can be effectively used in new structural elements at new construction as a working longitudinal or transversal reinforcement [2-4]. An effective version of the use of the cut and stretchy sheet is possible for the strengthening not only bending structures but also compressed and compressed out of center reinforced concrete and stone ones [5]. Thus, the issue of the research and modeling of the work of the steel cut and stretchy sheet in the array of concrete under the linear stressed state conditions is of vital importance.

The article presents the results of the experimental and theoretical research of the work of the steel cut and stretchy sheet under load; provided the physical model of such a process; substantiates the effectiveness of its use and the placement in span beam bridge structures.

2. Results and discussions

The relevance of the massive use of a steel cut and stretchy sheet for the reinforcement of steel concrete or reinforced concrete structures is due to the lack of a significant amount of experimental material regarding to the use of such sheet in the form of reinforcing core in stretched or compressed elements and an assessment of such type of reinforcement in the concrete environment of different classes and it leads to the non-use of such reinforcement in the design of elements of buildings and structures in the design and production practices. Therefore, at first concrete prisms reinforced with cut and stretchy sheet and made of different concrete types were investigated for tension for the effectiveness of the use of cut and stretchy sheet in spam beam structures. Researches were carried out in two stages.

The first stage included researching of a number of prisms merged into a series. Each series consisted of three concrete prisms. The first stage was made of concrete of type C8/10, the second one was made of concrete of type C16/20 and the last, the third series was made of concrete of type C25/30. All test samples were reinforced with a strip of cut and stretchy sheet (type 408), width of 100 mm, which were cut across the sheet. To fix the cut and stretchy sheet in tensile machine metal plates of metal sheet 3 mm thick were welded to the ends of the sheet strip (figure 1). The width of plates was taken as 100 mm.

![Figure 1.](image)

Figure 1. Reinforcement core of concrete prism in the form of a strip of cut and stretchy sheet

Plates were also 100 mm outside the concrete prisms. The strip of cut and stretchy sheet was centered and poured with concrete of different classes in a concrete prism. The dimensions of the concrete prisms of all series were taken as following: height 600 mm, width 150 mm, thickness 35 mm (figure 2).

Resarching of the concrete prisms for tension was conducted using the tensile machine. The prisms were fastened by metal shanks in the terminals of the tensile machine and were tested for tension. Loading was applied step by step, \( f = (0.05 \div 0.1) f_{\text{max}} \), with a break between them 20 \( \div \) 25 min.

The prisms were working as the integral monolithic unit under the tensile loading before cracks formation. There were a slight deformation at this stage and there were no fundamental changes in cut and stretchy sheet. In the process of increasing the tensile load, the first crack began to appear, which became critical. This crack in the tested prism arose approximately in the middle of the prism height.
and crossed immediately the prism. The nature of the crack formation was approximately the same for prisms of different concrete class but only the value of the tensile loading under which the crack appeared was different: for concrete type С8/10 – $F = 4.8$ t and for concrete type С16/20 – $F = 5.2$ t as well as for concrete type С25/30 – $F = 5.8$ t. The given behavior can be explained by different concrete strength for tension. The higher is the class of concrete, the greater is concrete resistance to this type of load, that is, the tension strength. The crack appeared immediately and crossed the prism almost immediately to the entire width of the prism (figure 3).

![Figure 2. Design of test samples of the first stage of the researches](image)

![Figure 3. Transversal crack formation in tested concrete prisms: a) concrete type С25/30; b) concrete type С16/20; c) concrete type С8/10](image)
Concrete crashing in the middle part of the prism began in all prisms in the process of further loading. At the same time concrete crashing was in the form of a strip approximately 1/3 of the width of the prism (figure 4).

![Concrete crashing of tested prisms](image1)

**Figure 4.** Concrete crashing of tested prisms

The process of concrete crashing was finished when the middle part of concrete prism fell completely out as the result the cut and stretchy sheet was getting bare. The high of crashed part in all prisms was approximately 1/3 of the high of the prism (figure 5).

![Baring and destruction of cut and stretchy sheet](image2)

**Figure 5.** Baring and destruction of cut and stretchy sheet
While concrete was crashing in prisms, the cells of the cut and stretchy sheet were extended and the cells of cut and stretchy sheet were destroying under further increasing of loading and the tested sample was destroyed. (figure 5)

During the experiment it could be seen that the destruction of all the tested samples occurred in almost the same way and therefore the form of destructed tested concrete prisms reinforced with cut and stretchy sheet was similar.

The second stage of research differed because the prisms were made in a thickness of 100 mm which led to a change in the destruction process of such prisms. The process of destruction was characterized by the fact of concrete lifting of cut and stretchy sheet but the sheet itself wasn't destroyed. The destructive loading increased again after rising of concrete type (figure 6).

The second stage was also distinguished by the fact that during prisms testing the deformation of the cell of cut and stretchy sheet took place under the process of loading of tested sample. The cell of the sheet was destroyed along and across. The research proved that the cell of cut and stretchy sheet under tension loading on concrete sample reinforced with cut and stretchy sheet is geometrically unchanged regardless the sample concrete type. Slight deformations are observed only in the samples made of concrete of low types.

Figure 6. Process of testing and destructing of prisms at the second stage (thickness of 100mm)

To evaluate better the behavior of the cut and stretchy sheet under loading we describe its physical model (figure 7) and provide only a real diagram of steel deformation of sheet which the cut and stretchy sheet is made of. It is rather difficult to obtain the destruction diagram of cut and stretchy sheet under laboratory conditions (figure 8).
Under condition of equilibrium we get the relationship between $N_1$ and $N_2$:

$$(2n+1)N_2 = 2nN_1 \Rightarrow N_1 = N_2 \frac{2n + 1}{2n} \quad (1)$$

Find the value of bending moment in sections 1, 2, 3:

$$M_1 = N_2 \frac{h}{2}; \quad M_2 = N_2h-N_1 \frac{h}{2} = N_2 \frac{h}{2} \frac{2n-1}{2n}; \quad (2)$$

$$M_3 = N_2 1,5h + N_20,5h - N_1h = N_2h \frac{2n-1}{2n}; \quad (3)$$

Find the maximum value of bending moment:

$$M_{\text{max}} = N_2h(n-0,5 + n-1,5 + \ldots + 0,5) - N_1h(n - 1 + n - 2 + \ldots 1) =$$

$$= N_2h \frac{n}{2} \frac{(n - 1)(2n + 1)}{2n}; \quad (4)$$

$$M_{\text{max}} = \frac{N_2h(n+1)}{4}; \quad (5)$$
If \( n = 3 \); \( M_{\text{max}} = N_2h \);

In addition to the bending moments in the rods, there are also longitudinal forces \( S_1 \) and transverse forces \( Q_1 \) namely:

\[
S_1 = N_2 \cos L; \\
Q_1 = N_2 \sin L; \\
S_2 = N_1 \cos L - N_2 \cos L = \frac{1}{2n} N_2 \cos L; \\
Q_2 = N_2 \sin L - N_1 \sin L = -\frac{1}{2n} N_2 \sin L; \\
S_3 = 2N_2 \cos L - N_1 \cos L = \frac{2n - 1}{2n} N_2 \cos L; \\
Q_3 = \frac{2n - 1}{2n} N_2 \sin L; \text{ and so on.}
\]

There are normal tensions from these power factors:

\[
\sigma_1 = \frac{S_1}{A_1} + \frac{M_1}{W_1}.
\]

3. Conclusions

Having summarized it can be defined the following:

a. The work of the cut and stretchy sheet under loading can be described with the help of the formula and shown in the form of physical model, however, it is better to estimate combined work of sheet and concrete by conducting the research, as well as having made the mathematic model of combined work of sheet and concrete the experimental and the theoretical values can be compared.

b. On the basis of conducted researches reinforced beam constructions are tested the cut and stretchy sheet is used as the additional reinforcement. As the result of such researches it was proved that the cut and stretchy sheet doesn’t require any additional means of combining facilities and it is of high operational reliability, it is important in designing and building of beam bridge structures.

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