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Selected findings from parametric studies determining the resistance of concrete panels in real terms

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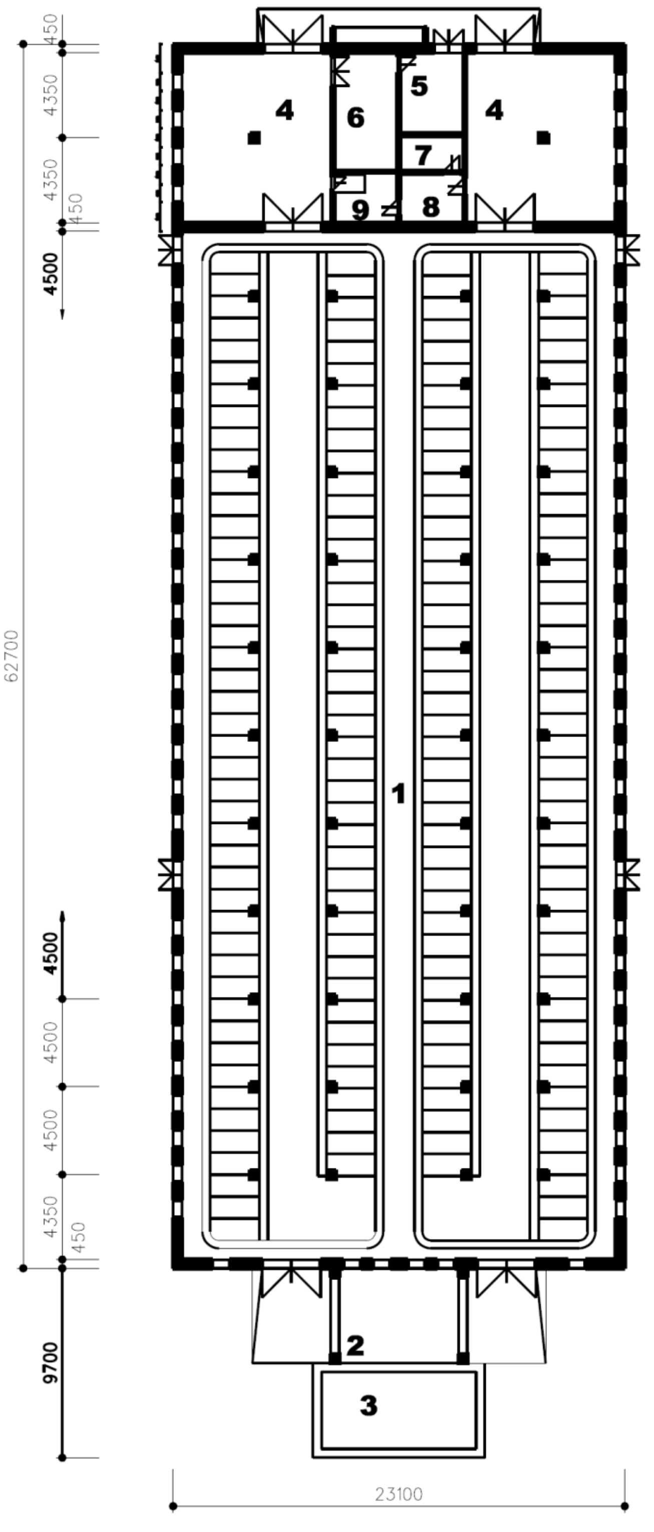
Abstract

In the article selected results of parametric analysis of lightened reinforced concrete panels used in agricultural objects are presented. The aim of the analysis was to devise a parametric model that can be later on used for the simulation of behaviour of real ceiling panels when changing pre-defined parameters.

Key words: concrete, steel reinforcement, ceiling panel, agricultural structure K-174, deflection, crack, parametric analysis.

1 Introduction

A change in the political regime in the 1990s led to a change in ownership relationships, including the ones in agricultural farming production. Nowadays, conditions of cattle breeding agricultural structures in Slovakia are considered unsatisfactory, both from operation and, to a large extent, static points of view. The structures serve their purpose despite their conditions and they can be assumed a threat not only to the livestock but to the staff as well. Therefore, it is important to look into this serious problem, it is inevitable to carry out regular inspections in the structures, and based on their results, to decide whether the structure is eligible for reconstruction or it is more appropriate for the structure to get demolished. The stable structures serviceability is mainly affected by the aggressive cow barn environment, so called cow barn microclimate, characterized by an excessive presence of harmful gases (hydrogen sulphate, ammonia, and carbon dioxide), dustiness, and humidity. A negative impact of these factors onto a structure is manifested by its degradation, while ceiling panels occur to be the most affected elements. During their production, regarding economy, they were preferred to be light and thin which has now resulted in a faster onset of the degradation process manifesting itself by the covering concrete layer fallen down, and concrete and reinforcement corrosions [2].



Legend

1- cowshed
2- shelter
3- midden
4-9- operating rooms

Figure 1: Object K - 174

2 Description of the object

The subject matter of the article is to analyze and evaluate ceiling panels conditions in the real environment of the cow barns of K-174 type (Fig. 1). This type of an agricultural structure is a standard representative of large capacity cow barns. The structure forms a separate closed technological operational livestock farming unit to stable 174 pieces of dairy cows [1].

2.1 Design considerations of concrete building structure

The subject matter is a general-purpose reinforced concrete prefabricated structure, combined with external load-bearing brick walls, and no loft (Fig. 2). It is a single-storey transit building built as a 5-nave structure with four longitudinal prefabricated reinforced concrete frames. The system altogether comprises ten elements, assembled as single-storey structures with cantilevered columns, single beams, and single embedded ceiling panels. The roof structure gradient is 10°. Module axes are spaced by 4500 mm and 6000 mm. The cow barn roof bearing structure consists of lightened ribbed reinforced concrete ceiling panels marked as SZD 10n – 450 (Fig. 3).

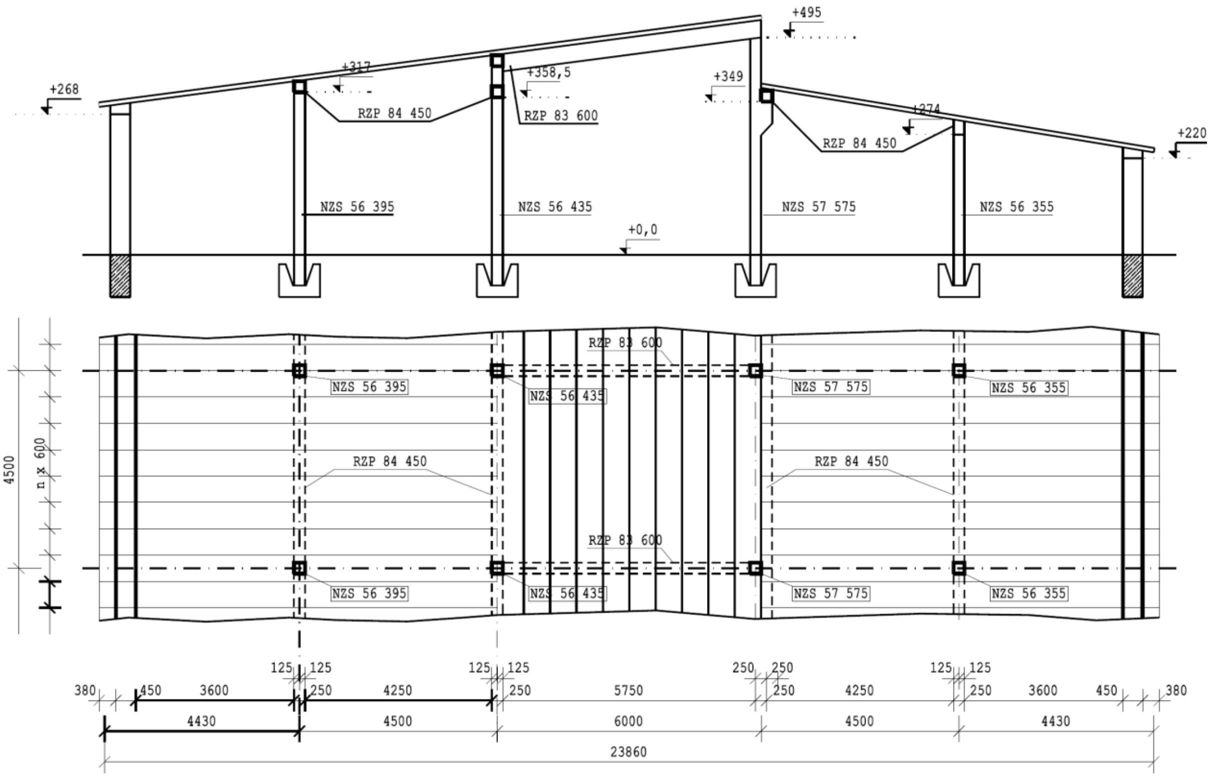


Figure 2: Scheme of composition of the object K - 174

2.2 The choice of carrying element for parametric study

As the subject matter of the study, we have chosen the most exposed element – a lightened panel (Fig. 3). Longitudinal panel ribs contain the main load-bearing longitudinal reinforcement (one stiffening rod of 8 mm in diameter) (Fig. 4). The reinforcement is anchored by cohesion or is welded to the transverse bars (of 6 mm in diameter). The panels were produced from concrete with strength of 25 MPa, the main load-bearing reinforcement used was of 350 MPa in strength, while the structural reinforcement was of 200 MPa in strength.

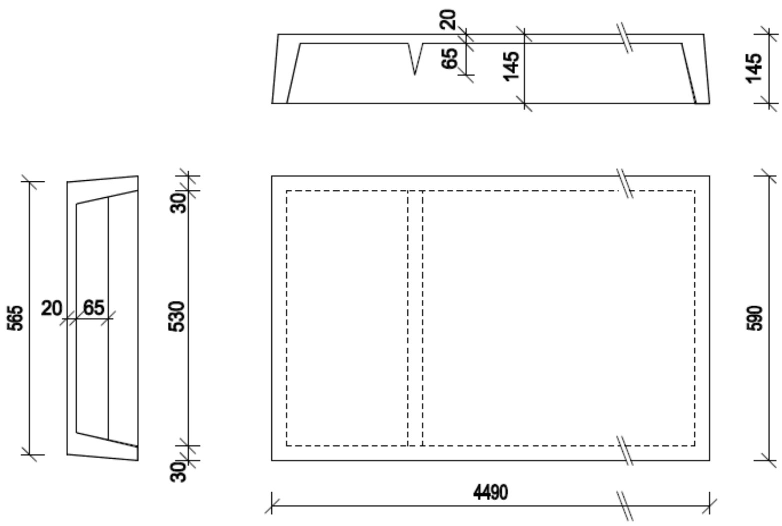


Figure 3: Concrete roof panel SZD 10n – 450

3 Parametric analysis

The analysis was aimed at designing such parametric models that could be used to simulate ceiling panels behaviour while changing chosen parameters under real conditions. For the purpose of the parametric analysis we used ATENA V4 software [3] which is based on the finite element method.

3.1 Modelling and calculation

Modelling of the chosen task was carried out in a ***pre-processing*** phase during which an input file was created in GiD software environment: element geometry, material characteristics editing, grid formation, setting calculation parameters and boundary conditions. In this mode, so-called ***monitors***, recording measured parameters, deflections and cracks, were set in specified monitored spots on the panel. Static tasks were modelled in ***Static*** software.
Loading was carried out by an increase in surface load, applied in partial values in a set number of steps. A hexagonal prism - ***Hexahedra element*** – was a preferred type of a finite

element. Therefore, the grid was formed by means of Hexahedra elements. To solve the task, we have chosen Newton-Raphson iteration method which is based on the principle of estimating a solution for unknown values and, in the following step, accuracy improvement for the previous solution is made. The correction process is repeated until the solution inaccuracy in individual iterations reaches a specified inaccuracy value [3].

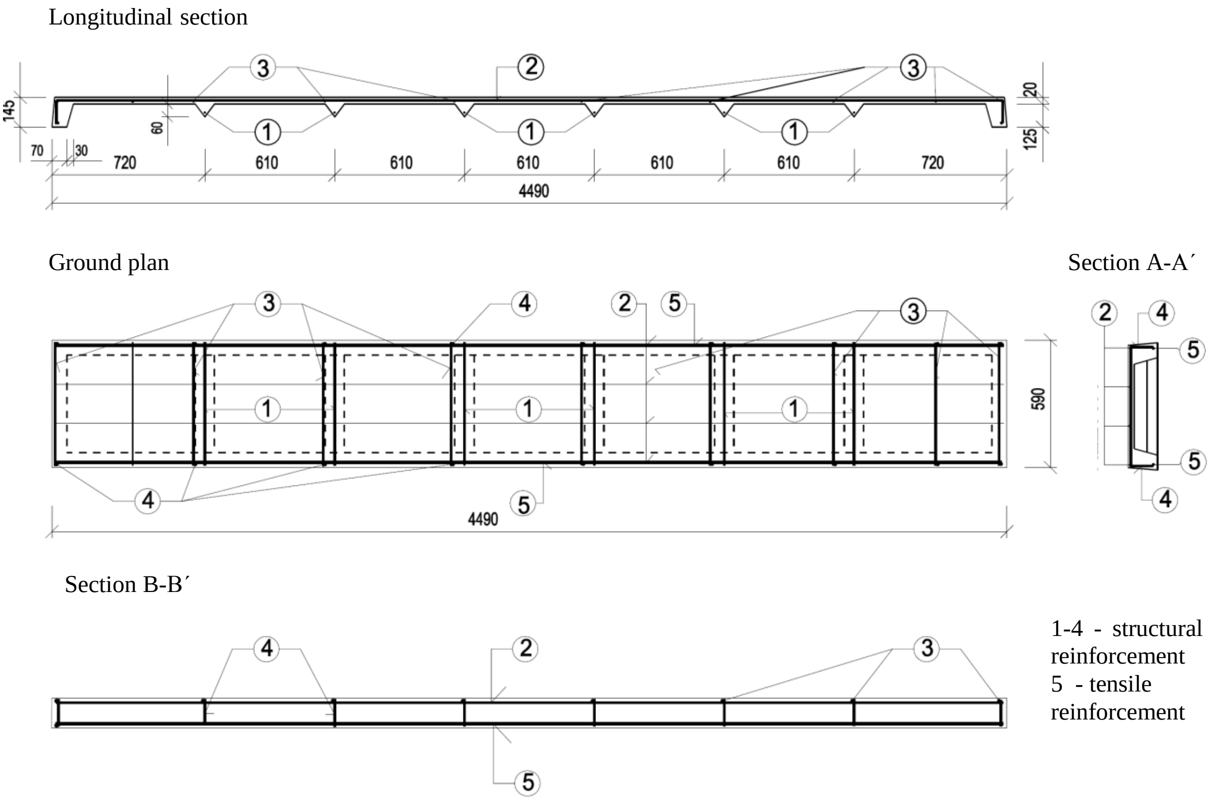


Figure 4: Scheme of reinforcement panel

The parametric model copied real dimensions and characteristics of the ceiling panel components, though transverse panel ribs were modified which led to a significant elimination of the number of necessary elements, and thus to the grid topography simplification. Altogether, the model comprised three types of materials, namely concrete, reinforcement, and a steel board which was used as a load spreading board at panel supporting areas to avoid local concrete failures at linear supports. The concrete model was set by ***SOLID Concrete*** material group, while a specific material, ***Cementitious2 (CC3DNonLinCementitious)***, combining basic models for tension and compression behaviour of concrete, was chosen [4]. The strength set by the design was 25 MPa and the measured strength was 23 and 21 MPa. The longitudinal tension reinforcement, and both strap and structural reinforcements were modelled as discrete 1D reinforcements, set by 1D Reinforcement – CCReinforcement material. In the analysis, the original 8 mm diameter of the longitudinal reinforcement, a presumed decreased 7 mm diameter (due to reinforcement corrosion), and an added 10 mm diameter (due to a substitution in some of the panels) were used. Material characteristics are presented in Table 1.

Table 1: Material characteristics for parametric simulation

	$f_{c\,,\,cube}$ [MPa]	25	23	21
Concrete	f_c [MPa]	21	19	17
	f_t [MPa]	2,301	2,180	2,050
	E_c [GPa]	28,062	27,065	26,003
Reinforcement	ø [mm]	8	10	7
	f_{sy} [MPa]	350	350	350
	E_s [GPa]	200	200	200
	f_{st} [MPa]	378	378	378

Legend:

$f_{c\,,\,cube}$ - cube strength of concrete
f_c - cylinder strength of concrete
f_t - tensile strength of concrete
E_c - elastic modulus of concrete
f_{sy} - strength of reinforcement (yield strength steel)
E_s - elastic modulus of reinforcement
f_{st} - tensile strength of reinforcement - f_{sy} . k (k = 1,08)

The last variable parameter in the analysis was the concrete covering, i.e. the original designed value 10 mm and values found out by examination, 20 and 30 mm. For the parametric study we prepared 27 panels (beams) labelled as NVK (beam / reinforcement / concrete covering). The list of the panels with input parameters is shown in Table 2.

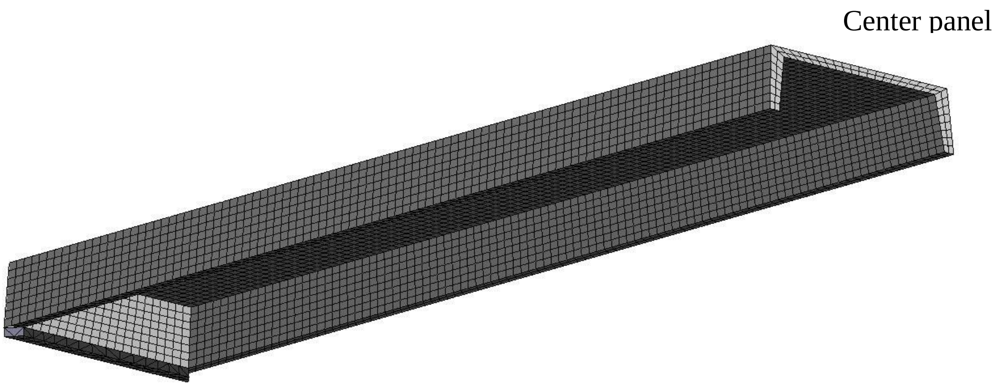


Figure 5: Model of panel

Due to symmetry, it was sufficient to model only a half of the panel which decreased the calculation time. A parametric model of a panel shaped as a finite element grid is shown in Fig. 5.

3.2 Parametric simulation of panel action

Behaviour of the panel obtained from the parametric simulation is presented by a deflection-load ratio and crack topography. Fig. 6 shows a demonstration of panel deformation with recorded deflection values, while Fig. 7 presents the crack topography. A half of the panel is presented.

Table : 2 Input parametes of panel

Input parametes			
Panel labelling	Concrete fck $_{cube}$ [MPa]	Reinforcement diameter ø [mm]	Concrete cover [mm]
N1V1K1	25	8	10
N1V1K2	25	8	20
N1V1K3	25	8	30
N1V2K1	25	10	10
N1V2K2	25	10	20
N1V2K3	25	10	30
N1V3K1	25	7	10
N1V3K2	25	7	20
N1V3K3	25	7	30
N2V1k1	23	8	10
N2V1K2	23	8	20
N2V1K3	23	8	30
N2V2K1	23	10	10
N2V2K2	23	10	20
N2V2K3	23	10	30
N2V3K1	23	7	10
N2V3K2	23	7	20
N2V3K3	23	7	30
N3V1K1	21	8	10
N3V1K2	21	8	20
N3V1K3	21	8	30
N3V2K1	21	10	10
N3V2K2	21	10	20
N3V2K3	21	10	30
N3V3K1	21	7	10
N3V3K2	21	7	20
N3V3K3	21	7	30

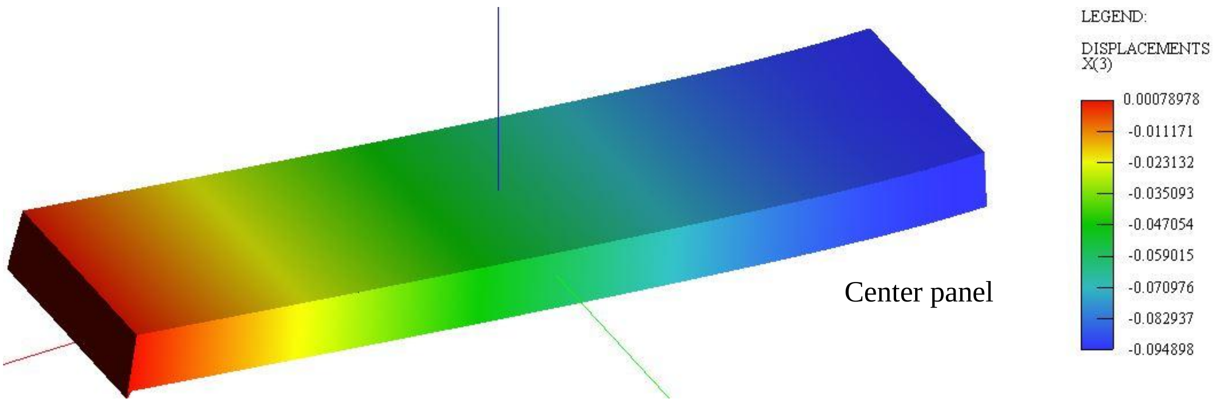


Figure 6: Deflection panel

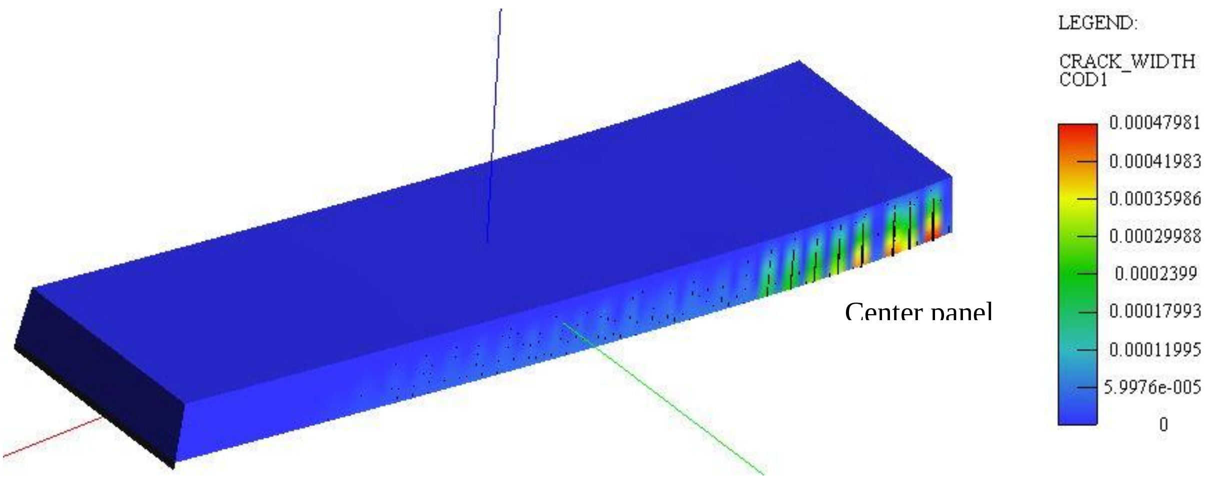


Figure 7: The bending cracks panel

3.3 Results of parametric analysis

Behaviour of one of the panels is shown in Fig. 8 where, for illustration, the deflection-load ratio diagram for panel N1V1K1 is shown. For each model, load values and deflections were calculated while reaching limit crack widths according to [5], w_{max} = 0,3 mm (XC3 environment class) and w_{max} = 0,4 mm (max. bar diameter), and load values were calculated while reaching limit deflection values (l / 100, l / 250). For N1V1K1 panel, the calculated values are presented in Table 3.

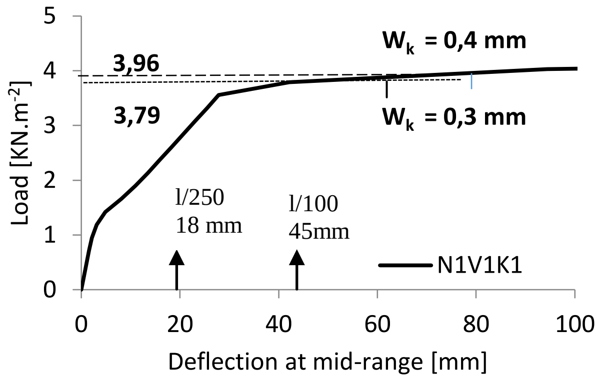


Figure 8: Stress strain diagram –panel N1V1K1

Table 3: Calculated values of load factor and deflection

Labelling panel	Load factor on reaching the limit value [kN/m^{-2}]				Deflection on reaching the limit value [mm]	
	Deflection l/100= 45mm	Deflection l/250 =18mm	Crack w_{max} = 0,3 mm	Crack w_k = 0,4 mm	Crack w_{max} = 0,3 mm	Crack w_k = 0,4 mm
N1V1K1	5,26	2,58	3,89	3,96	59,57	78,94

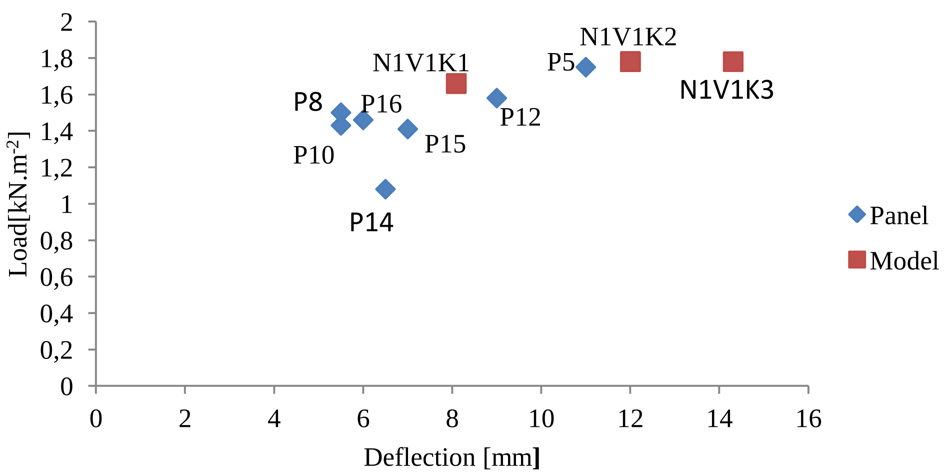


Figure 9: A comparison of cracking limit

4 Conclusion

The parametric study pointed out possible roof panels behaviour from a possible change of chosen parameters point of view. Based on the result analysis of the designed parametric models, it is possible to conclude the following:

- Ultimate crack formation was reached in physical panels at a lower load, which corresponds with a high level of panel degradation (Fig. 9).
- In loading the model, when reaching the limit deflection, the crack width does not exceed a limit value.
- A good correspondence between model and physical panels behaviours was proved while observing the original parameters, which means that ceiling panels resistance is still sufficient from their static behaviour point of view. It was proved that the reinforcement position significantly affects the panel deflection.

Based on the above mentioned findings, it is possible to conclude that the examined ceiling is not in such a critical condition that would inevitably require its removal. However, it is necessary to slow down the degradation process by a suitable reconstruction, and to eliminate the unfavourable impact of the aggressive cow barn environment by suitable means.

References

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