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DETERMINATION OF ELASTIC SURFACES FOR CONTIUNUOUSLY LOADED MDF PANELS

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ABSTRACT
The MDF panels are storaged by arranging in packets, consequently divided by base traverses. The panels are therefore deformed due to storing height, large distance among base traverses, and misalignment of base traverses. The research proved that the importance of storing is underestimated. The goal of this work is to calculate the optimum distance among base traverses, namely to estimate the adequate level of bending of the most strained board in order to be within acceptable limits. This paper gives comparison between numerical, analytical and experimental results.
Keywords: elastic surface, MDF, continuous load, optimum distance

1. INTRODUCTION
MDF (Mitteldichtefaserplatte) is commercial name for panels made of processed wooden waste. They are also known in USA as "Boraboard" panels. These panels are in wide use as a material for production of furniture, machinery or buildings. One of their major disadvantages is their likeliness to be deformed. These deformations occur during their storage, and it is necessary to determine the best way to support them during storage phase. This research was performed in order to find the optimum support layout, and it included analytical, experimental and numerical methods to obtain elastic surfaces for these panels in typical storage layout.

2. BACKGROUND AND PREVIOUS RESEARCH RESULTS
Current research results about deformation of MDF panels could be summarized as follows:
- Deformation measurements are performed rarely,
- Only a few countries have standardized allowed deformation limits for these panels,
- Countries with narrow limits for deformation errors (these limits were established according to insufficient researches) hardly realize these standardized values,
- In common practice, deformation is usually larger than 3.5 mm/m, which is the value obtained by measuring carefully chosen panels,
- There is no enough data available about common causes for these deformation, as well as about influence of these errors to their exploitation,
- There is no enough data available about influence of these errors to further processing of these panels,

3. RESULTS OF NUMERICAL ANALYSIS

Numerical analysis is performed by means of commercial Finite Element Software "I-deas Master Series v.8". Total weight of one panel is:

$$F = \rho \, h \, d \, L \, g = 779{,}22 \text{ x } 0{,}019 \text{ x } 1{,}53 \text{ x } 2{,}75 \text{ x } 9{,}81 = 611{,}09 \text{ N}. \quad \text{... (1)}$$

If each odd panel is discretized with 40 finite elements per length, with support in each odd node and with force F_{20} in each even node, this force is:

$$F_{20} = F / 20 = 611{,}09 / 20 = 30{,}555 \text{ N} \quad \text{... (2)}$$

If each even panel is discretized with 40 finite elements per length, with support in each even node and with force F_{21} in each odd node, this force is:

$$F_{21} = F / 21 = 611{,}09 / 21 = 29{,}10 \text{ N} \quad \text{... (3)}$$

Finite element method gives values of reactions in supports. These values are then used as a load for next panel, increased by the weight of next panel. The same calculations were performed for 30 panels, and results showed that only first 3 to 4 supports at both ends of panel have different results, while all other results are constant. That means that load is mainly continuous and regularly distributed over the whole length of the panel. That means that analysis could be performed with single panel loaded with continuous load, which consists of weights of all 30 panels above.

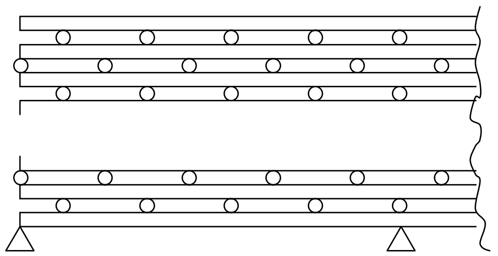


Figure 1. Schematic layout of supports for FEM calculation.

Table 1. Maximum deflection in [mm] for various supporting layouts

Panel with 4 supports (916)						
Field	1	2	3			
Defl.	14,8	1,35	14,8			
Panel with 5 supports (687)						
Field	1	2	3	4		
Defl.	4,23	0,77	0,77	4,23		
Panel with 6 supports (550)						
Field	1	2	3	4	5	
Defl.	1,55	0,27	0,71	0,27	1,55	
Panel with 5 supports, with free ends (570)						
Field	1	2	3	4	5	6
Defl.	1,75	0,26	0,69	0,69	0,26	1,75

Figures 2 to 5 show results of finite element analysis of bottom panel, loaded continuously by weight of 30 panels above. The deflection showed is visualized non-proportionally to show the location of maximum deflection. Numerical results are given in Table 2.

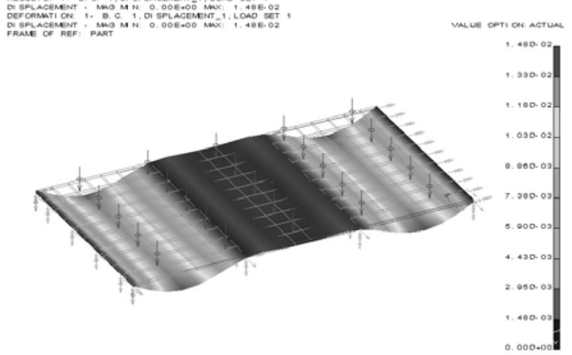


Figure 2. Panel with 4 supports (916)

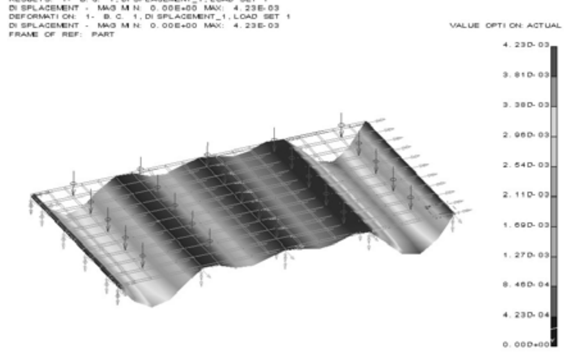


Figure 3. Panel with 5 supports (687)

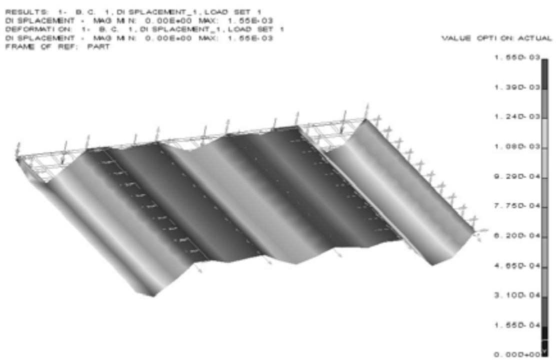


Figure 4. Panel with 6 supports (550)

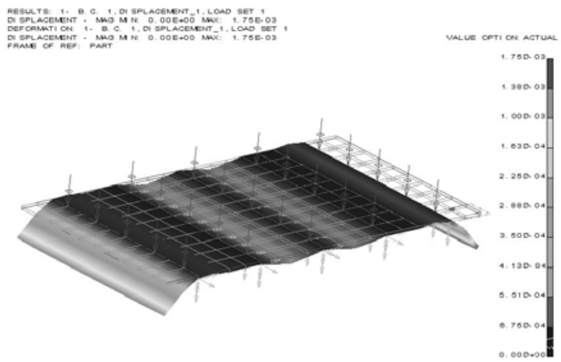


Figure 5. Panel with 5 supports, free ends (570)

4. ANALYTICAL ANALYSIS

There are a number of analytical methods for determination of deflections and stresses in continuously loaded plates: Navier's Solution, Fourier's Method, Complex Variable Method, Deformation Energy Method and Three Moments Method. The latter will be used in this case, since it is the most appropriate to be programmed in Fortran. This method will be used to calculate maximum deflection for various number of supports and to choose optimum solution, with deflection less than 1.5 mm, as requested by German MDF panel producers.

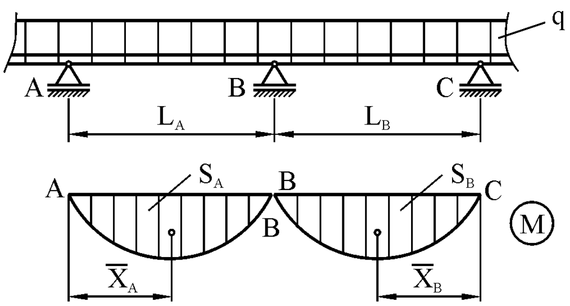


Figure 6. Beam with 3 supports

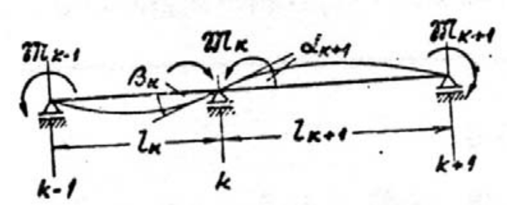


Figure 7. Three Moments Theorem [2]

$$\mathrm{M}_A \cdot \mathrm{L}_A + 2\,\mathrm{M}_B \cdot (\mathrm{L}_A + \mathrm{L}_B) + \mathrm{M}_C \cdot \mathrm{L}_B = -\frac{6 \cdot S_A \cdot \overline{X}_A}{L_A} - \frac{6 \cdot S_B \cdot \overline{X}_B}{L_B} \qquad \text{... (4)}$$

$\mathrm{M}_A, \mathrm{M}_B, \mathrm{M}_C$ – Bending moments in supports A, B, C.

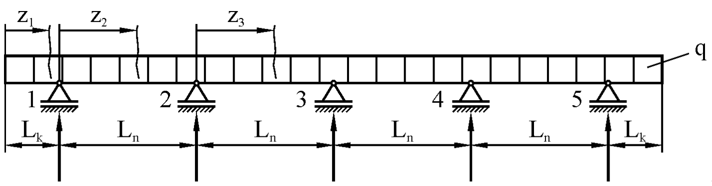
$\mathrm{L}_A, \mathrm{L}_B$ – length of beam between supports.

$\mathrm{S}_A, \mathrm{S}_B$ – area of moment diagram between supports, observed separately.

$\mathrm{X}_A, \mathrm{X}_B$ – datum of center of gravity of these areas.

Since moments in B are relatively small, they can be neglected, and equation (4) can be used for beam and panels with 3 supports. For beams and panels with more than 3 supports, equations is:

$$M_{k-1} \cdot l_k + 2M_k \cdot (l_k + l_{k+1}) + M_{k+1} \cdot l_{k+1} = 6EI_x \left[\sum(\alpha_{k+1}) - \sum(\beta_k)\right] \qquad \text{... (5)}$$



$L_n = 570mm$, $L_k = 235mm$

Figure 8. Panel with 5 supports and with free ends (case 570)

Results are given in Table 2, along with experimental and numerical results.

5. EXPERIMENTAL ANALYSIS

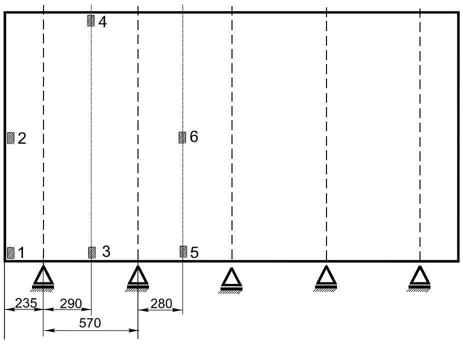


Figure 9. Measurement points for panel 916

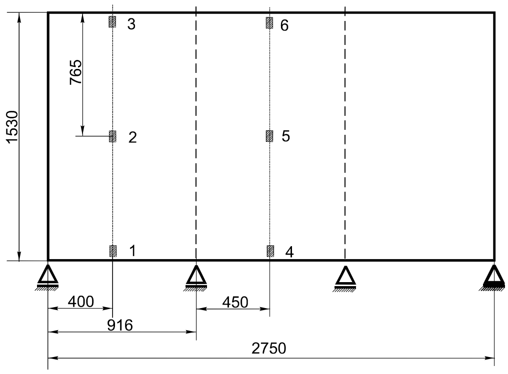


Figure 10. Measurement points for panel 570

Figures 9 and 10 show the layout of measurement points for panels 916 and 570. The deflection was measured in 6 points for 4 cases of supporting. The results are given in table 2.

Table 2. Maximum deflection in [mm] for various supporting layouts

Panel with 4 supports (916)			
Field	1	2	3
FEM	14,8	1,35	14,8
Analytical	15,28	1,15	15,28
Experiment	14,55	1,12	14,55

Panel with 5 supports (687)				
Field	1	2	3	4
FEM	4,23	0,77	0,77	4,23
Analytical	4,54	1,32	1,32	4,54
Experiment	4,38	1,28	1,28	4,38

Panel with 6 supports (550)					
Field	1	2	3	4	5
FEM	1,55	0,27	0,71	0,27	1,55
Analytical	1,89	0,44	0,91	0,44	1,89
Experiment	1,84	0,43	0,89	0,43	1,84

Panel with 5 supports, with free ends (570)						
Field	1	2	3	4	5	6
FEM	1,75	0,26	0,69	0,69	0,26	1,75
Analytical	1,27	0,84	0,87	0,87	0,84	1,27
Experiment	1,22	0,82	0,84	0,84	0,82	1,22

6. CONCLUSION

All three methods showed that minimum deflection of panels occurs when they are supported with 5 supports, with free ends. The three-moment theorem was successfully applied in computer program, which can be used to obtain optimum layout of supports for any similar panel.

The general conclusion is that the proper layout of supports can be easily implemented to avoid deformation of panels during storage phase, which could last for months and even years. The deformation occurs due to changes in humidity, temperature and other climate factors. These factors can be compensated with optimum supporting layout.

7. REFERENCES

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