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DETERMINATION OF REQUIRED STRENGTH OF MDF BLANK FINGER JOINT

The main areas of application of MDF linear elements are analyzed; techniques for determining required strength of MDF blank finger joint have been devised; shown here are a Linear-element load diagram and a shear-and-bending moments diagram; a relationship between a breaking and design bending moments is specified; also, a required relative strength of MDF linear-element finger joint has been determined.
Key words: finger joint, absolute strength, relative strength, a shear-and-bending moments diagram, a bending breaking moment, cross-breaking strength.

Linear elements are long pieces of lumber of various cross-sections which are used for decorative and fastening work [5]. The term “Linear element” derives from the word-combination “Linear metre”, thus the term is used to refer to wooden work (parts) whose main quantitative characteristic is their length which is measured in linear metres. Common examples of articles that are measured in linear metres are rope, cable, ducting, etc.

In woodworking, linear elements are those articles whose length considerably exceeds their width and thickness, and which have a certain profile, e. g. wooden lining, block-house, baseboard, casing, baguette and others. The raw material used for manufacturing linear elements include both solid wood and composite materials [7-13]. At present, among the composite materials which are used for manufacturing linear elements, the mast popular are medium density fiberboards (MDF), which have the following advantages over solid wood: lower price, absence of natural defects, more amenable to milling, etc.

The major areas of MDF linear-elements application are as follows:

- furniture pieces: a) fronts of frame-panel structures; b) furniture cornices; c) bull noses for furniture pieces; d) decorative furniture elements, etc;
- construction and millwork articles: a) door casing; б) baseboard; в) decorative ornamental elements; г) other components of construction and millwork articles.

According to European expertise Ukraine’s usage of MDF makes up over 180 thousand cubic metres a year while the total annual cost of their import amounts to 41 Mio. USD [6]. Because Ukraine does not have any factories producing MDF, we have to import all the needed amounts of this material, which increases the product’s price and, consequently, the cost of end-product. In view of this, it has become an urgent necessity of rational use of this material.

The rational use of MDF can be made possible not only by increased effective output during the process of cutting but by utilization of the cutting wastes as well.

One way of utilization of wastes from MDF cutting is their conversion into blanks of size smaller then that of the wastes themselves. An example of such usage is manufacturing linear elements from MDF cutting wastes [6]. A peculiarity of this production is that MDF elements are to be end-jointed. Taking into account the fact that linear elements from end-jointed MDF is innovation and MDF finger joints have not been studied yet, it is necessary to substantiate the required strength of finger joints of MDF members which would meet the production and operating requirements.

When employing finger joint for jointing solid wood parts, two kinds of strength are distinguisher: absolute and relative. Absolute strength represents maximum load that a specimen (a part) made of certain material can withstand. Relative strength is the ratio of a glued finger joint strength to solid wood strength expressed in percent.

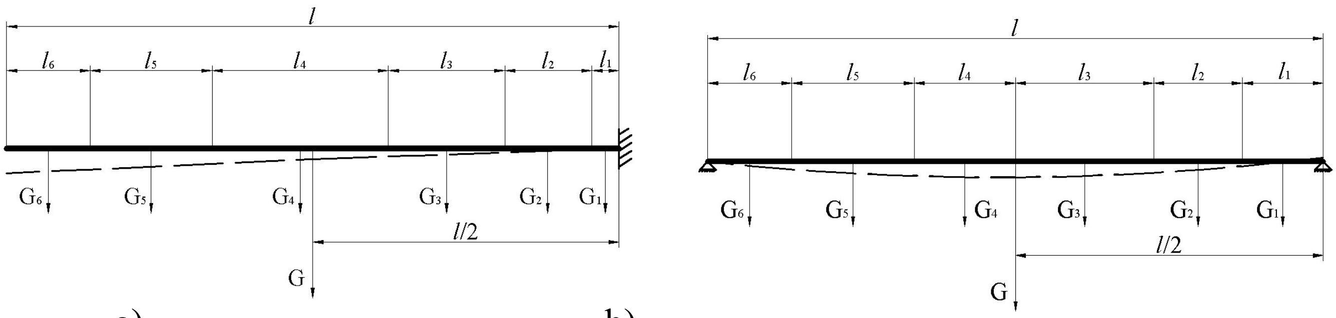
The absolute and relative strengths of glued finger joint are determined by cross-breaking testing. In order to quickly evaluate the performance of finger joints under operating conditions, specimens cut out of glued finger jointed blanks are used. Finger joint are subdivided into two categories according to their relative strength value:

- I – with relative strength not less than 75 %, including joints which undergo great external loading. For solid wood these are max-tenons (50 and 32 mm long);
- II – with relative strength not less then 60 %, including joints with middle and mini-tenons (solid wood), tenon's length being 5; 10 and 20 mm.

Since we are dealing here with specimens made of MDF rather than of solid wood, we shall use non-glued MDF pieces as the basis for determining relative strength.

From the above listed areas of MDF linear elements applications, it is clear that MDF linear elements undergo but slight static loads under operation conditions, therefore, to determine required finger joint strength we shall take linear elements loads emerging during manufacturing and transporting, in order to determine the required finger joint strength.

The major portion of static loads acting on finger joints during manufacturing and transporting is associated with the proper weight of MDF linear elements. In accordance with the principles of theoretical mechanics [2], let us construct a load diagram for linear elements (fig. 1) involving two cases: rigid fastening of one end (scheme 1); cantilever fastening of both ends (scheme 2). Where $\boldsymbol{l}$ is overall length of the linear element, m; $\boldsymbol{l_1}$–$\boldsymbol{l_6}$ is the length of individual parts of linear elements, m; $\boldsymbol{G}$ – total weight of the linear elements, N; $\boldsymbol{G_1}$ – $\boldsymbol{G_6}$ is the weight of individual parts of the linear elements, N.



a) b)

Fig. 1. Linear-element load diagrams:
a) – diagram No. 1 – rigid fixing; b) – diagram No. 2 – cantilever fixing of both ends

There is a standard identifying the techniques and procedure of testing glued finger joint for cross-breaking strength [4]. While observing the same principles of theoretical mechanics, let us construct a simplified diagram of a loaded test specimen during the determination of a finger joint cross-breaking strength (fig. 2).

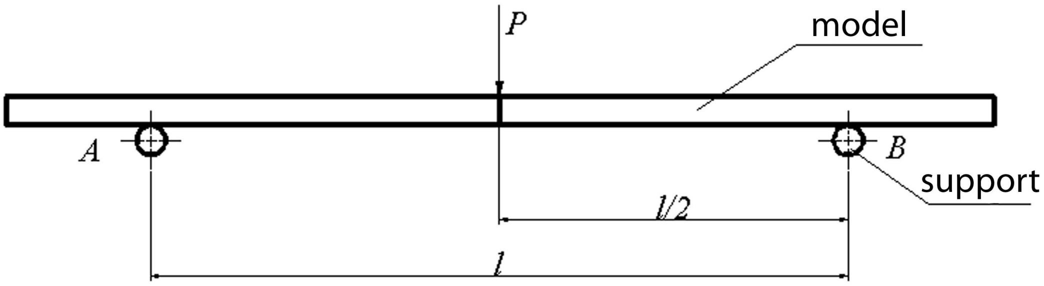


Fig. 2. Load diagram of a test specimen during determination of cross-breaking strength for finger joint

On the basis of the load diagram constructed, perform calculations for a breaking moment of test specimen as well as a design maximum bending moment.

The procedure of relative strength determination for MDF linear element finger joint is based on the comparison between the breaking bending moment for a solid test specimen and design bending moment for the linear element.

This technique is based on the strength condition under normal stresses [1]:

$$\sigma_{\max} = \frac{M_{\max}}{W} \leq [\sigma], \tag{1}$$

where: σ_{max} – maximum design stress; $[\sigma]$ – allowable normal stress; M_{max} – maximum bending moment; W – section modulus.

Thus, the expression for the allowable bending moment will have the form:

$$|M| = W \cdot [\sigma] \tag{2}$$

Since the allowable stress for the same material is a constant, and section modulus for all specimens of linear elements of the same profile is also alike, the allowable bending moment will also be alike. Therefore, to determine required relative strength, one can use the comparison of breaking moment of a test specimen with maximum design moment specified for a certain type of linear element load:

$$\%_{B.M.} = \frac{|M_{\max\ des.}|}{|M_{br}|} \cdot 100, \tag{3}$$

where: $M_{max\ des}$ – maximum design moment; M_{br} – breaking moment (bending moment at whit test specimen failure occurs).

Taking into account dynamic loads emerging in the process of manufacturing and transporting as well as other types of contingent loads, the final formula for determination of required relative strength of a MDF linear element finger joint will read:

$$\%_{B.M.} = \frac{|M_{\max\ des.}|}{|M_{br}|} \cdot 100 \cdot n, \tag{4}$$

where n – a reserve strength factor.

For determination of M_{br}, let us use unjointed MDF linear element specimens of ten various types which will be tested for cross-breaking strength. The bending moment that arises at point of applied load (fig. 2), will amount to:

$$|M_A| = |M_B| = |P \cdot l/2| \tag{5}$$

Hence, it follows that the value for the cross-breaking moment will amount to the product of breaking force by the spacing between the point of support and the point of this force application (fulcrum):

$$M_{br} = |P_{br} \cdot l/2| \tag{6}$$

The results of testing unjointed MDF linear-element specimens for cross-breaking force and moment for each type of profile are given in table 1.

To determine the maximum design bending moment, let us divide the linear elements into characteristic section, the boundaries of which are possible placer of jointing, then mark cross forces and bending moments on these sections.

The weight of each individual element, and thus the total weight of the linear elements, will be changed to uniformly distributed loads.

A shear-and-bending moments diagram for loaded No. 1 and ПР17 is exemplified in fig. 3.

Table 1. Results of testing unjointed MDF linear-element specimens for cross-breaking strength

No	Linear element profile	Cross-section dimensions, mm		Spacing between support points, mm	Breaking force, N	Breaking moment, N•m
		width	thickness			
1	Casing MC (No1)	80	16	230	2317.7	266.1
2	Casing MC (No2)	80	16	230	2012.9	231.5
3	Casing semi round	70	16	230	2036.1	234.1
4	ПР4 cornice	70	16	230	1751.0	201.4
5	КМ6 cornice	70	16	230	1803.5	207.4
6	Front No1	60	16	230	1527.0	175.6
7	Front No2	60	19	230	1756.1	202.0
8	ПР17	50	16	230	1411.4	162.3
9	ПР13	40	19	230	1307.2	150.3
10	ПР16	30	16	230	1064.3	122.4

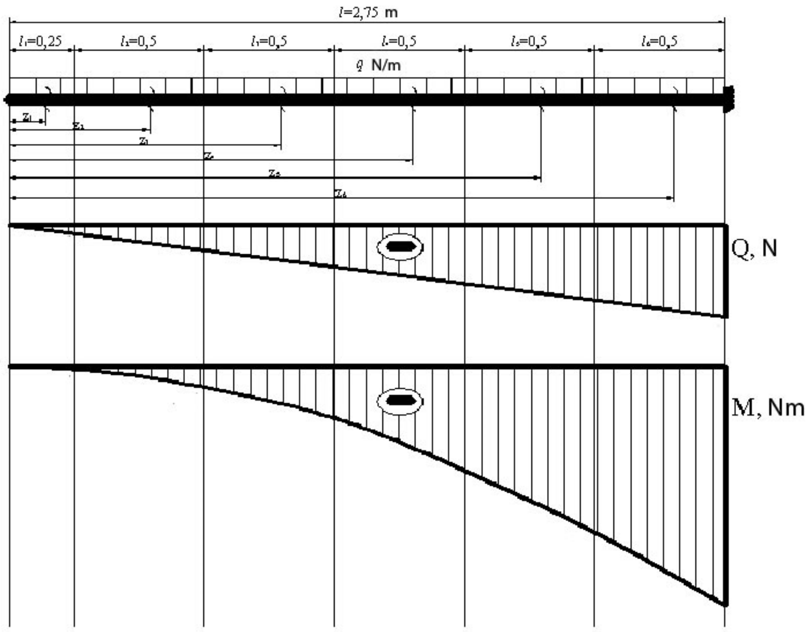


Fig. 3. An example of a shear Q and bending moments M for load diagram No. 1

The results of computation for all the ten types of linear elements as well as load diagrams No. 1 and No. 2 are given in table 2.

Table 2. Results of determination of the maximum design bending moment

No	Linear element profile	Dimensions, mm			q, N/m	Maximum bending moment, N•m	
		width	thickness	length		loading diagram No 1	loading diagram No 2
1	Casing MC (No 1)	80	16	2.75	9.09	34.36	27.49
2	Casing MC (No 2)	80	16	2.75	8.43	31.89	25.51
3	Casing semiround	70	16	2.75	7.74	29.28	23.43
4	ПР4 cornice	70	16	2.75	7.26	27.46	21.97
5	КМ6 cornice	70	16	2.75	7.13	26.94	21.55
6	Front No 1	60	16	2.75	6.68	25.25	20.20
7	Front No 2	60	19	2.75	7.95	30.07	24.05
8	ПР17	50	16	2.75	6.21	23.48	18.79
9	ПР13	40	19	2.75	5.37	20.30	16.24
10	ПР16	30	16	2.75	3.44	13.02	10.41

On the basis of the computed values obtained, construct a plot of the bending moment distribution as functions of width and length of the linear-element material for both load diagrams (fig. 4 and fig. 5).

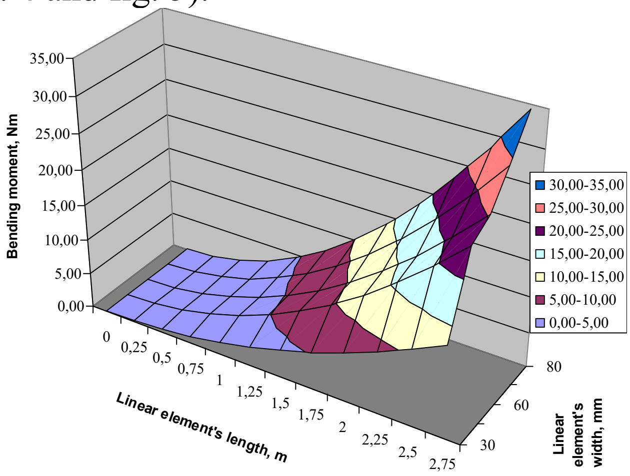


Fig. 4. Distribution of design bending moment for load diagram No. 1

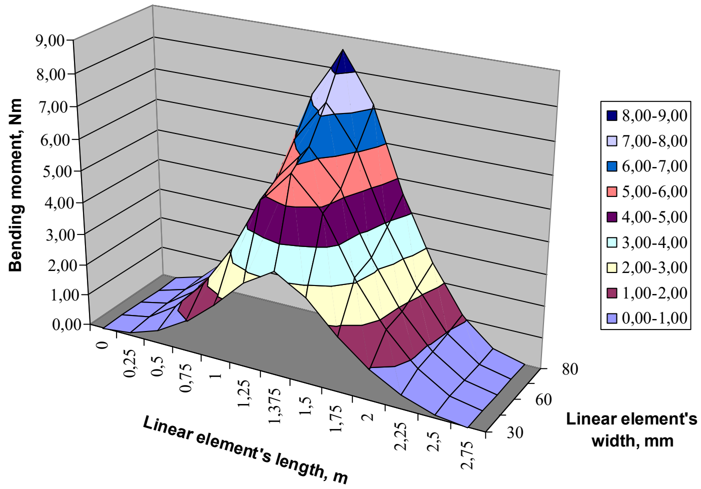


Fig. 5. Distribution of design bending moment for load diagram No. 2

With the data on the breaking and design bending moments available, calculate their relationship by the formula 3 (table 3). Since the tabulated relationship of the breaking and design bending moments do not take into account dynamic and other contingent loads, the identification of their values as those of required relative joints, is impermissible. Finally, the required relative strength is determined with consideration for the reserve strength factor (formula 4) whit is in the range from 3 to 4 for dynamic loads.

Table 3. Relationship between a breaking and design lending moments

No	Linear element profile	Cross-section dimensions, mm		Bending moment, N•n		Relationship between a breaking and design lending moments, %
		width	thickness	breaking (experimental)	maximum design	
1	Casing MC (No 1)	80	16	266.1	34.36	12.91
2	Casing MC (No 2)	80	16	231.5	31.89	13.78
3	Casing semiround	70	16	234.1	29.28	12.51
4	ПР4 cornice	70	16	201.4	27.46	13.63
5	КМ6 cornice	70	16	207.4	26.94	12.99
6	Front No 1	60	16	175.6	25.25	14.38
7	Front No 2	60	19	202.0	30.07	14.89
8	ПР17	50	16	162.3	23.48	14.47
9	ПР13	40	19	150.3	20.30	13.51
10	ПР16	30	16	122.4	13.02	10.64

At the reserve-strength factor value like this and the maximum moments relationship of 14.89 % (see Table 3), the required relative strength will amount to:

$$\%_{B.M.} = \frac{|M_{\max des.}|}{|M_{br}|} \cdot 100 \cdot n = 14{,}89 \cdot 3 \ldots 4 = 44{,}67 \ldots 59{,}56\ \%.$$

Conclusions. The procedure for determining required relative strength of MDF linear-element finger joints has been devised. In future, this procedure can be used at enterprises for a quick determination of finger joint strength. The distribution of bending moments as functions of width and length of a profile has been identified. It has been found that the required strength of MDF finger joint equals to 44.67…59.56 % given the reserve strength factor is *n*=3…4.

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Визначення необхідної міцності зубчастого шипового з'єднання заготовок з MDF

Проаналізовано основні сфери застосування погонажних елементів із MDF, розроблено методику визначення необхідної міцності зубчастого шипового з'єднання заготовок із MDF, наведено схеми навантаження погонажу та епюру поперечних сил і згинальних моментів, встановлено співвідношення руйнівного та розрахункового згинальних моментів, визначено необхідну відносну міцність зубчастого шипового з'єднання погонажних елементів із MDF.

Ключові слова: зубчасте шипове з'єднання, абсолютна міцність, відносна міцність, епюра поперечних сил та згинальних моментів, руйнівний згинальний момент, міцність на статичний згин.