ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XIX, NR. 1, 2012, ISSN 1453 - 7397

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On the Mesh Influence upon the Frequency Results Obtained by FEM Simulations

The paper presents a research performed by the authors, in order to establish the optimal element dimensions for a given beam, so that FEM simulations should offer highest accuracy by minimum time consumption. To achieve this desire, we made FEM simulations with elements of various dimensions for seven cross-section dimensions

Keywords: *beam, natural frequency, FEM analysis, mesh, error*

1. Introduction

Finite element method is a method of numerical analysis and simulation of the process and technical phenomena. The main idea of the method consists in dividing the geometric model in finite elements connected in common points (nodes). Thus, the entire pattern analysis is regarded as a discrete network elements interconnected [1]. Operation is automatic meshing by dividing the geometric model in finite elements, this operation is referred to as mesh, the size of the element can be defined by the researcher. The end result of meshing (the number of nodes and finite elements generated) depend on the geometry and dimensions of the model, the quality of the item required (draft-coarse or high-fine), the size of the item, the tolerances required for meshing, local conditions of mesh and contact conditions specified. It is recommended for the initial calculations to generate some coarse sizes of meshes with finite element to obtain quick solutions, and in the early stages of a meshes must be made with fine sizes of finite element in order to increase the precision of final solutions generated by this method. You can also enforce local mesh in areas where the size of the variable geometry, finite element can be finer than the rest areas. In the case of analysis with solid models can be used tetrahedral or hexahedral elements, the latter offering more precise results. The mesh is smoother, more time and better precision and vice versa.

The purpose of the work is to determine the optimum size of the elements for a given case, so that the results of simulations should be precise enough without being time-consuming.

2. Beam modeling using hexahedral elements

The analysis is performed on a steel beam [2] shown in Figure 1, with the physical and mechanical properties set out in table 1 and geometrical characteristics presented in table 2.

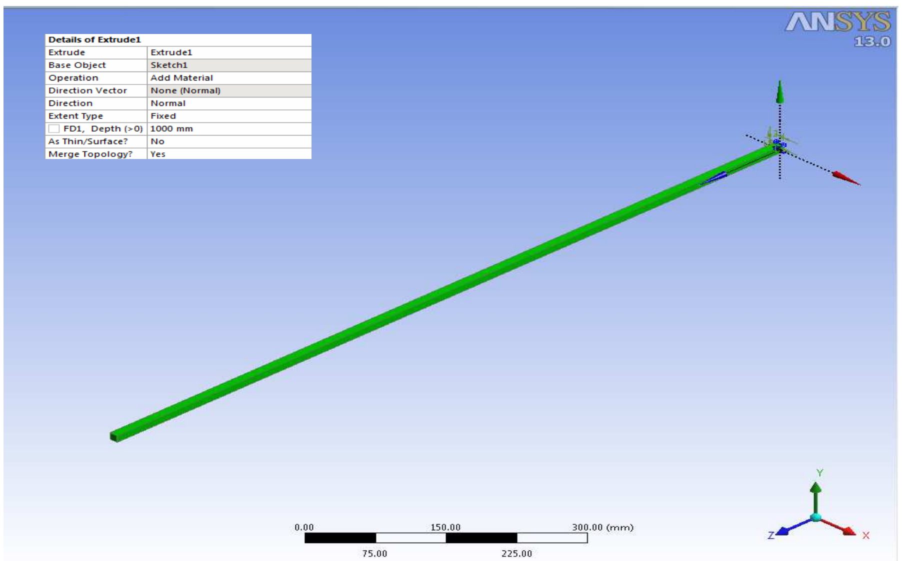

Figure 1. Analyzed steel beam

Table 1

Physical&mechanical properties	U.M.	Value
mass density	kg/m^3	7850
Youngs modulus	N/m^2	$2,0 \times 10^{11}$
Poissons ratio	-	0,3

Table 2

Lenght *L* [m]	High *H* [m]	Wide *B* [m]	Cross-section *A* [m^2]	Moment of inertia *I* [m^4]
1	0,011	0,011	$1,21\times10^{-4}$	$1,22008\times10^{-9}$
1	0,012	0,012	$1,44\times10^{-4}$	$1,728\times10^{-9}$
1	0,013	0,013	$1,69\times10^{-4}$	$2,38008\times10^{-9}$
1	0,014	0,014	$1,96\times10^{-4}$	$3,20133\times10^{-9}$
1	0,015	0,015	$2,25\times10^{-4}$	$4,21875\times10^{-9}$
1	0,016	0,016	$2,56\times10^{-4}$	$5,46133\times10^{-9}$
1	0,020	0,020	$4,00\times10^{-4}$	$1,33333\times10^{-9}$

The mesh was created with finite elements of different dimensions, in 7 cases, shown in table 3; the meshed beam's 3D representation and the cross-sections are presented in figures 2, 3 and 4.

Table 3

Cross-section *B×H* [mm]×[mm]	Element type	Finite element dimension [mm]							
11×11	Hexahedral element	1	2	3	4	5	6	7	8
12×12		1	2	3	4	5	6	7	8
13×13		1	2	3	4	5	6	7	8
14×14		1	2	3	4	5	6	7	8
15×15		1	2	3	4	5	6	7	8
16×16		1	2	3	4	5	6	7	8
20×20		1	2	3	4	5	6	7	8

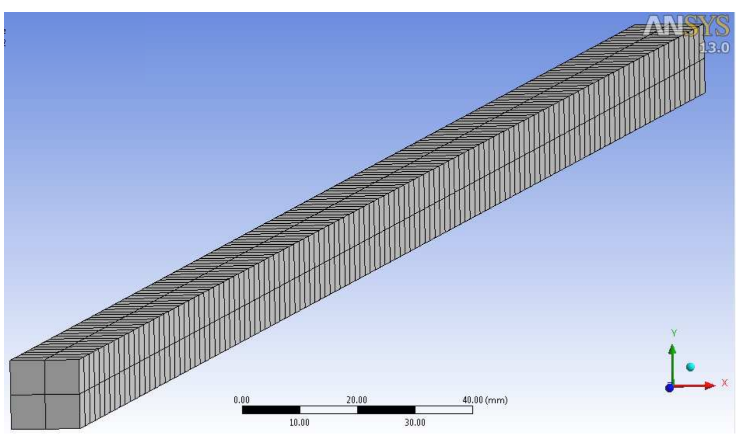

Figure 2. Meshed beam in 3D representation

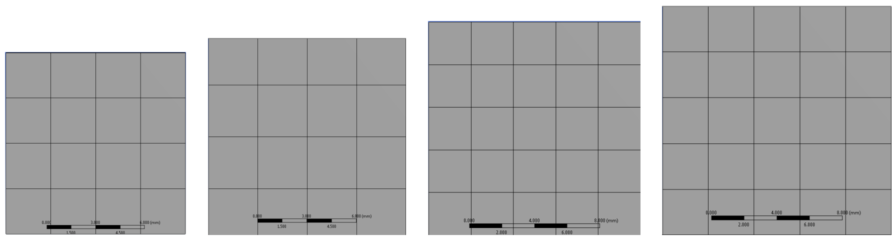

Figure 3. Transversal meshed sections for beams with cross-section 11×11; 12×12; 13×13 and 14×14

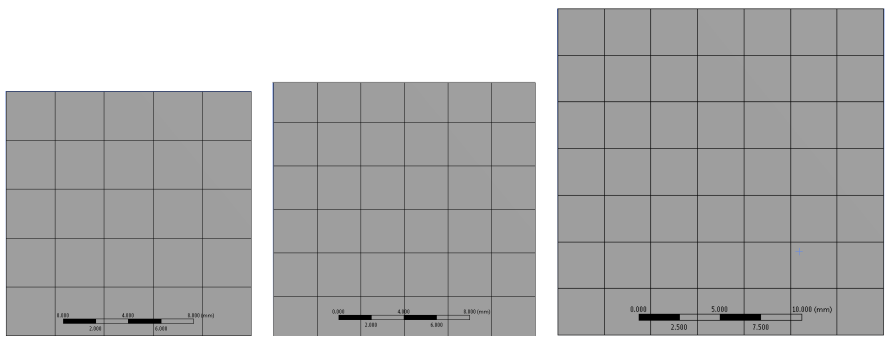

Figure 4. Transversal meshed sections for beams with cross-section 15×15; 16×16 and 20×20

Analyzing the scales in figures 3, 4 and 5, one can conclude that, by setting a finite element of given dimension, the program adjust its dimension in concordance to the cross-sections shape and dimensions.

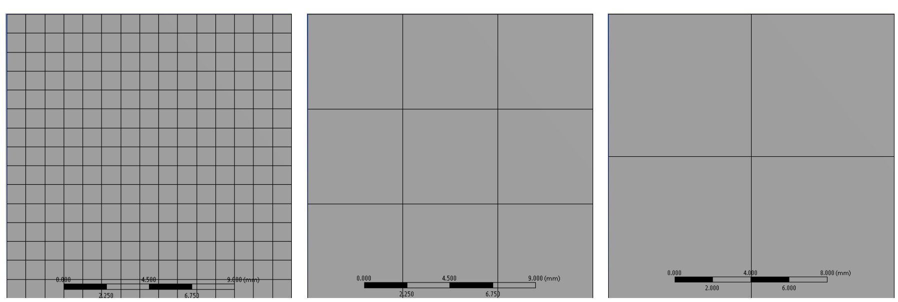

Figure 5. Cross-section of 15×15 mm meshed with 1 mm, 5 mm and 8 mm elements respectively

3. Results and discussions

The Euler-Bernoulli model permits easily to calculate the natural frequencies for beams with low rigidity [5]. For rigid beams, where the shear effect is more dominant than the bending one, other models are more appropriate. The shear model, for instance, leads to precise results and use low resources, because adding shear to an Euler-Bernoulli beam produce a refine of natural frequencies.

Because the beam is short (L = 1000 mm) comparing with the rigidity, it's applied analytical calculation for shear model for all sections, as outlined above, the very first 10 values of natural frequencies presented in table 4.

Table 4

Mode *i* / Beam type	1	2	3	4	5
11×11	8.9685	56.1808	157.1993	307.7373	508.0472
12×12	9.7837	61.2824	171.4514	335.5735	553.8655
13×13	10.5989	66.3824	185.6934	363.3733	599.5887
14×14	11.4140	71.4808	199.9245	391.1339	645.2093
15×15	12.2291	76.5774	214.1438	418.8523	690.7198
16×16	13.0441	81.6721	228.3506	446.5257	736.1129
20×20	16.3037	102.0295	285.0361	556.7118	916.3669
Mode *i* / Beam type	**6**	**7**	**8**	**9**	**10**
11×11	757.7169	1056.2890	1403.2216	1797.8946	2239.6133
12×12	825.8021	1150.7927	1528.1398	1957.0471	2436.6260
13×13	893.6820	1244.9067	1652.3841	2115.1144	2631.9853
14×14	961.3406	1338.6014	1775.9053	2272.0199	2825.5794
15×15	1028.7621	1431.8482	1898.6556	2427.6902	3017.3023
16×16	1095.9313	1524.6188	2020.5888	2582.0550	3207.0536
20×20	1361.7871	1890.4078	2499.2880	3185.1729	3944.5528

From numerical simulations using the finite element method we obtained the natural frequencies presented in table 5; one can see a good correlation between the results obtained by analytical calculations and that obtained by numerical simulations. The results allow to plot figures 6 and 7, which show influence of the finite element's size upon the accuracy in determining the natural frequencies of beams, with significant impact on the possibility of determining the exact position of the damage defect in straight beams [3] and [4].

Table 5

	Mode shape	Mesh							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
11×11	**1**	8.9729	8.9732	8.9735	8.9738	8.9739	8.9746	8.9749	8.9751
	2	56.2007	56.2022	56.2041	56.2062	56.2070	56.2117	56.2131	56.2144
	3	157.2211	157.2254	157.2307	157.2370	157.2393	157.2532	157.2571	157.2608
	4	307.6850	307.6937	307.7044	307.7173	307.7217	307.7513	307.7590	307.7663
	5	507.7603	507.7750	507.7932	507.8154	507.8228	507.8764	507.8891	507.9013
	6	756.9266	756.9489	756.9769	757.0117	757.0230	757.1111	757.1303	757.1488
	7	1054.597	1054.6291	1054.6695	1054.720	1054.7369	1054.8729	1054.9002	1054.9264
	8	1400.084	1400.1276	1400.1831	1400.254	1400.2770	1400.4776	1400.5146	1400.5505
	9	1792.608	1792.6637	1792.7373	1792.834	1792.8639	1793.1493	1793.1980	1793.2456
	10	2231.301	2231.3720	2231.4671	2231.596	2231.6332	2232.0274	2232.0901	2232.1521
12×12	**1**	9.7889	9.7892	9.7895	9.7899	9.7901	9.7908	9.7911	9.7913
	2	61.3048	61.3067	61.3088	61.3113	61.3122	61.3173	61.3189	61.3203
	3	171.4705	171.4757	171.4818	171.4890	171.4916	171.5071	171.5115	171.5156
	4	335.4880	335.4985	335.5108	335.5254	335.5307	335.5639	335.5725	335.5807
	5	553.4653	553.4829	553.5039	553.5294	553.5383	553.5989	553.6134	553.6270
	6	824.7384	824.7652	824.7975	824.8377	824.8512	824.9522	824.9741	824.9948
	7	1148.552	1148.5908	1148.6376	1148.696	1148.7162	1148.8738	1148.9048	1148.9344
	8	1524.026	1524.0782	1524.1425	1524.226	1524.2526	1524.4872	1524.5293	1524.5697
	9	1950.164	1950.2316	1950.3172	1950.431	1950.4659	1950.8023	1950.8577	1950.9113
	10	2425.868	2425.9528	2426.0633	2426.214	2426.2590	2426.7266	2426.7978	2426.8676
13×13	**1**	10.6049	10.6052	10.6055	10.6058	10.6062	10.6064	10.6073	10.6076
	2	66.4075	66.4092	66.4111	66.4129	66.4159	66.4168	66.4232	66.4248
	3	185.7079	185.7130	185.7182	185.7236	185.7322	185.7347	185.7541	185.7587
	4	363.2467	363.2561	363.2666	363.2774	363.2951	363.3002	363.3417	363.3508
	5	599.0522	599.0679	599.0857	599.1042	599.1350	599.1436	599.2195	599.2349

Table 5 (continued)

	Mesh								
	Mode shape	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
13×13	**6**	892.2921	892.3172	892.3445	892.3731	892.4217	892.4348	892.5613	892.5846
	7	1242.0186	1242.0541	1242.0932	1242.1346	1242.206	1242.2254	1242.4229	1242.4560
	8	1647.1255	1647.1736	1647.2270	1647.2842	1647.385	1647.4116	1647.7057	1647.7509
	9	2106.3743	2106.4337	2106.5039	2106.5802	2106.718	2106.7532	2107.1746	2107.2346
	10	2618.3936	2618.4713	2618.5612	2618.6601	2618.844	2618.8888	2619.4741	2619.5523
14×14	**1**	11.4210	11.4213	11.4216	11.4219	11.4224	11.4226	11.4236	11.4239
	2	71.5084	71.5104	71.5125	71.5146	71.5178	71.5189	71.5258	71.5276
	3	199.9324	199.9383	199.9442	199.9502	199.9598	199.9627	199.9838	199.9890
	4	390.9562	390.9671	390.9790	390.9913	391.0110	391.0169	391.0627	391.0729
	5	644.5088	644.5276	644.5478	644.5688	644.6033	644.6133	644.6981	644.7152
	6	959.5666	959.5961	959.6271	959.6596	959.7144	959.7296	959.8724	959.8983
	7	1334.9571	1334.9988	1335.0433	1335.0905	1335.171	1335.1937	1335.4186	1335.4556
	8	1769.3208	1769.3767	1769.4375	1769.5028	1769.618	1769.6482	1769.9854	1770.0360
	9	2261.1372	2261.2100	2261.2899	2261.3771	2261.535	2261.5750	2262.0611	2262.1281
	10	2808.7491	2808.8399	2808.9421	2809.0554	2809.265	2809.3173	2809.9956	2810.0828
15×15	**1**	12.2370	12.2373	12.2377	12.2381	12.2386	12.2388	12.2390	12.2402
	2	76.6074	76.6094	76.6120	76.6144	76.6180	76.6192	76.6202	76.6286
	3	214.1426	214.1484	214.1560	214.1628	214.1734	214.1768	214.1797	214.2054
	4	418.6131	418.6236	418.6391	418.6529	418.6748	418.6815	418.6875	418.7431
	5	689.8267	689.8455	689.8717	689.8954	689.9339	689.9453	689.9554	690.0585
	6	1026.5426	1026.5718	1026.6120	1026.6488	1026.710	1026.7276	1026.7430	1026.9166
	7	1427.3337	1427.3753	1427.4329	1427.4863	1427.577	1427.6029	1427.6252	1427.8986
	8	1890.5544	1890.6117	1890.6903	1890.7642	1890.894	1890.9289	1890.9597	1891.3693
	9	2414.3778	2414.4518	2414.5550	2414.6538	2414.832	2414.8783	2414.9196	2415.5095
	10	2996.8231	2996.9112	2997.0430	2997.1714	2997.409	2997.4690	2997.5232	2998.3453

Table 5 (continued)

	Mode shape	Mesh 1	2	3	4	5	6	7	8
16×16	**1**	13.0530	13.0534	13.0537	13.0542	13.0544	13.0551	13.0552	13.0566
	2	81.7043	81.7066	81.7087	81.7122	81.7132	81.7174	81.7186	81.7276
	3	228.3377	228.3442	228.3501	228.3603	228.3632	228.3757	228.3791	228.4068
	4	446.2142	446.2259	446.2378	446.2584	446.2644	446.2903	446.2970	446.3578
	5	734.9976	735.0192	735.0393	735.0747	735.0849	735.1304	735.1418	735.2556
	6	1093.2046	1093.2360	1093.2667	1093.3216	1093.3374	1093.4099	1093.4274	1093.6207
	7	1519.1170	1519.1653	1519.2090	1519.2888	1519.3115	1519.4197	1519.4450	1519.7518
	8	2010.7836	2010.8459	2010.9053	2011.0158	2011.0468	2011.2010	2011.2359	2011.6983
	9	2566.0274	2566.1086	2566.1863	2566.3336	2566.3748	2566.5865	2566.6334	2567.3022
	10	3182.5147	3182.6145	3182.7131	3182.9042	3182.9573	3183.2397	3183.3012	3184.2360
20×20	**1**	16.3173	16.3177	16.3182	16.3188	16.3193	16.3195	16.3205	16.3207
	2	102.0684	102.0711	102.0739	102.0777	102.0814	102.0827	102.0890	102.0905
	3	284.9450	284.9526	284.9608	284.9716	284.9825	284.9863	285.0049	285.0094
	4	555.9849	555.9972	556.0136	556.0354	556.0577	556.0656	556.1045	556.1137
	5	914.0304	914.0544	914.0822	914.1194	914.1580	914.1715	914.2406	914.2564
	6	1356.3237	1356.3613	1356.4035	1356.4607	1356.5212	1356.5420	1356.6533	1356.6777
	7	1879.7062	1879.7603	1879.8200	1879.9023	1879.9907	1880.0208	1880.1882	1880.2237
	8	2480.6432	2480.7140	2480.7944	2480.9068	2481.0298	2481.0712	2481.3111	2481.3605
	9	3155.3122	3155.4053	3155.5094	3155.6572	3155.8220	3155.8772	3156.2079	3156.2748
	10	3899.7159	3899.8297	3899.9607	3900.1492	3900.3634	3900.4350	3900.8771	3900.9657

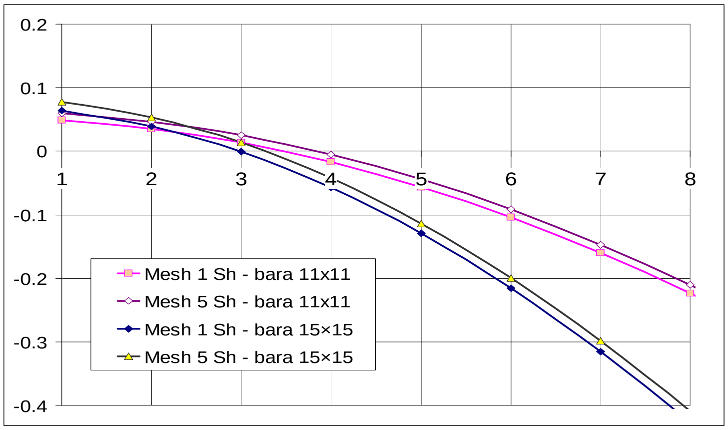

Figure 6. Errors for beams of cross-section 11×11 mm and 15×15 mm

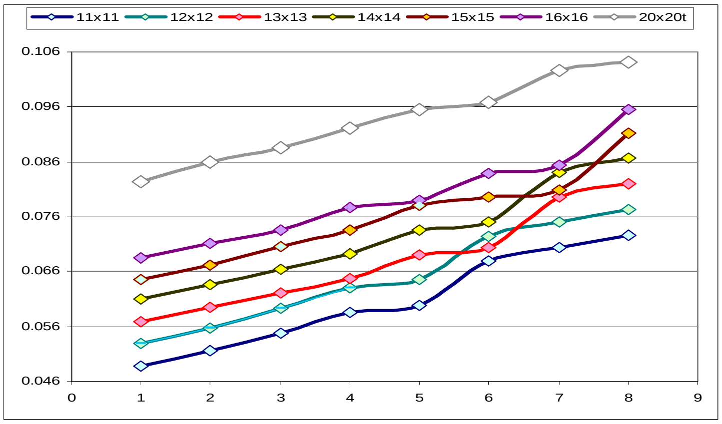

Figure 7. Errors for the first mode of beams wit various cross-sections

4. Conclusion

The analyses made by using finite element method showed that the size of the mesh of structure elements that influence the accuracy of the results. As a result of simulations studied, we came to the conclusion that the relationship between the dimension and precision of these elements is not linear, but depends largely on the size and shape and mechanical structures modeled; a greater accuracy is achieved when the side beam is not exactly the dimension of the element between what she meshing the beam.

Acknowledgement

The work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Romanian Ministry of Labour, Family and Social Protection through the Financial Agreement POSDRU/88/1.5/S/61178 and POSDRU/107/1.5/S/76813.

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