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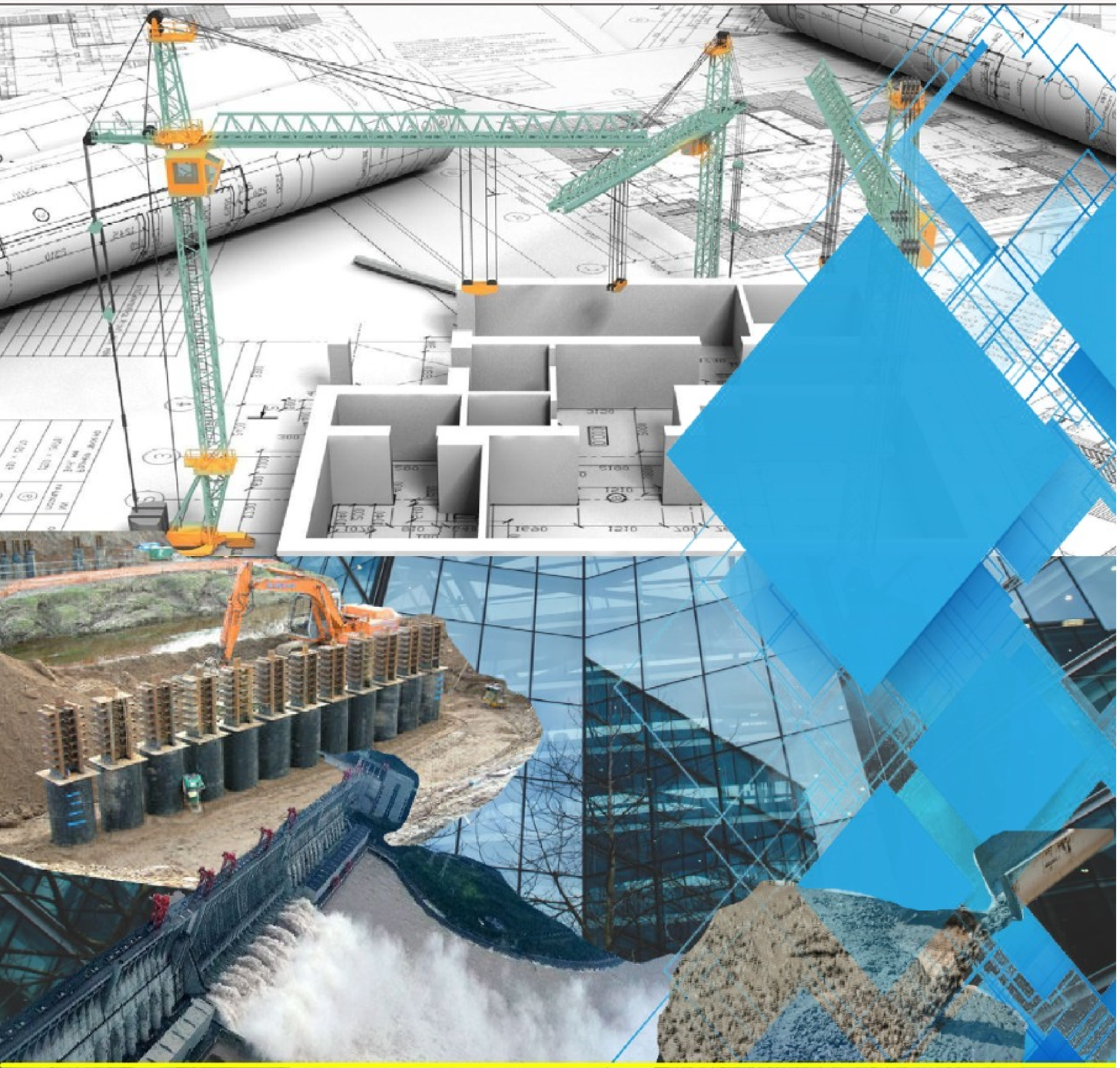

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CASTELLATED STEEL BEAMS EFFICIENCY BY TOPOLOGY OPTIMIZATION

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A B S T R A C T

Topology optimization is a mathematical method which spatially optimizes the distribution of material within a defined domain, by fulfilling given constraints previously established and minimizing a predefined cost function. For such an optimization procedure, the three main elements are design variables, the cost function and the constraints. The purpose Topology optimization IWF steel profiles of 300x150x6.5x9 offers to leverage the advancement in manufacturing technologies that have made it possible to fabricate castellated materials with complex but prescribed topologies, especially the use of wide span beams and high rise buildings that require many beam openings as heating, ventilation and air conditioning (HVAC) lines. Castellated beam has the ability to carry a greater moment and greater stiffness. To determine the relationship between the layout model IWF steel profiles of 300x150x6.5x9 will be carried out FEA Analysis with several volume ratio constraints of 0.5; 0.4 and 0.3. Topology optimization results will be verified and validated with castellated beam product by PT.Gunung Garuda Steel Group which is widely used in the Indonesian market.

1. Introduction

The development of cutting tools and welding machines has resulted in the development of the use of steel shapes that are used especially for industrial building structures that have wide spans and high-rise building applications that require many beam openings as heating, ventilation and air conditioning (HVAC) lines, explained in Figure 1. One that is currently developing is the castellated beam and cellular beam models. The

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development of mathematics and optimization encourages the use of modern optimization techniques [1] and [2] such as metaheuristic optimization (Genetic Algorithm, Particle swarm optimization, Fuzzy, etc.) which can produce optimum steel weight. Another optimization technique that is currently developing with Finite Element Analysis, one of which is Topology Optimization, this is because it can provide a figure of the shape, location and size of the hole opening which we will apply to the IWF steel profile castellated beam product from PT.Gunung Garuda Steel Groups that we encounter a lot of use in construction practice in Indonesia.

Figure 1. Application of Perforated Steel in high rise building
(reff : http://www.steelconstruction.info)

2. Research Method

In this study, the material used was mild steel standard ASTM A36/JIS SS400/BJ 37 with a yield strength value of fy=240 Mpa and a breaking value of fu=400 Mpa. Topological Optimization Analysis is used by modeling IWF beams of 300x150x6.5x9 which are fabricated into castellated beam profiles into CAS dimensions of 450x150x6.5x9, modeled on simple supports with a span length of 5m, carried out with finite element analysis, topology optimization assisted by software. ***Altair Hyperworks Inspire*** [3] as shown on Figure 22.

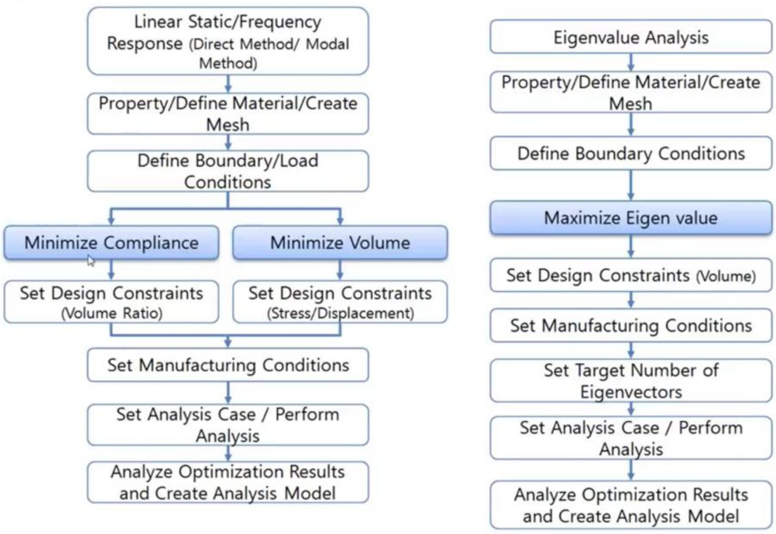


Figure 2. FEA Optimized Topology Evaluation

3.1 Description and Technical

Structural topology optimization is divided into 3 (three) different types, each targeting different types of parameters, namely: topology optimization, size optimization and shape optimization, described in Figure 4. Topology optimization is the most common type of structural optimization, which is carried out in the early stages of design, all parameters are considered to achieve the objective function. The initial model of the optimization topology gives a 70% figure of the objective function, described in Figure 3, which can be refined (fined-tune) and with different volume ratios, other types of optimization such as size optimization and shape optimization are not discussed. [4]

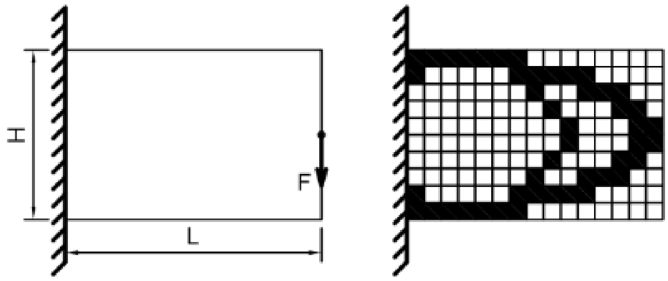


Figure 3. Typical Topology Optimization

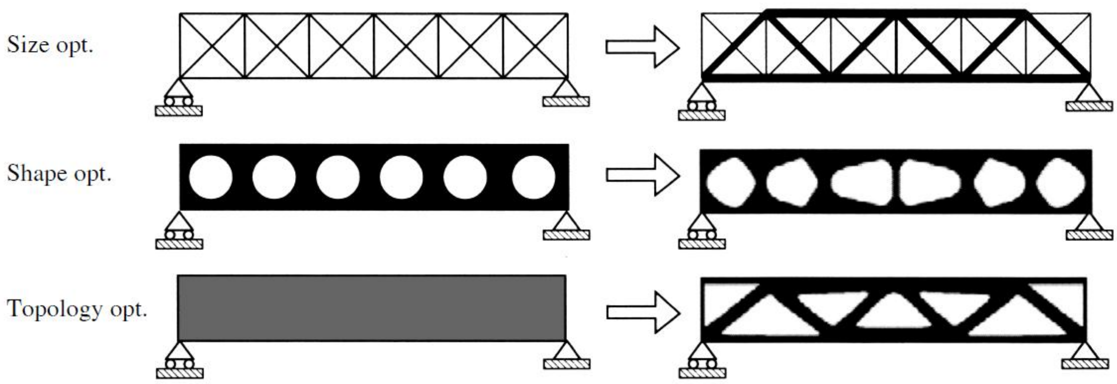


Figure 4. Topology Optimization Target Parameters

Topology optimization focuses on identifying the optimum members and opening locations, [5] Topology optimization can be completed with two technical approaches, namely material (micro approach) and geometry (macro approach), micro approach with Solid Isotropic Material with Penalization (SIMP) method using finite element analysis and search algorithm for optimal layout based on density method principle with set 0 for the material to be removed and set 1 for the material that remains so that it forms a pattern based on the objective function and the constraints of the constraint function, also explained by Bendsoe [6].

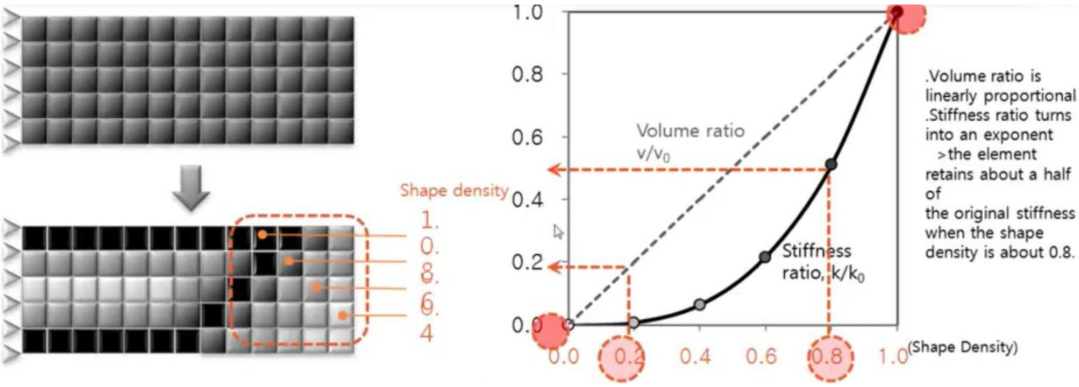


Figure 5 Density Method forms a layout pattern

Figure 5 explained that the volume ratio will remain the same following the shape density ratio while the stiffness ratio will form an exponential pattern when the stiffness ratio was 0.8 then the shape density ratio was 0,5. Figure 6 explain the stages of finite element analysis, topology optimization assisted by software. ***Altair Hyperworks Inspire***.

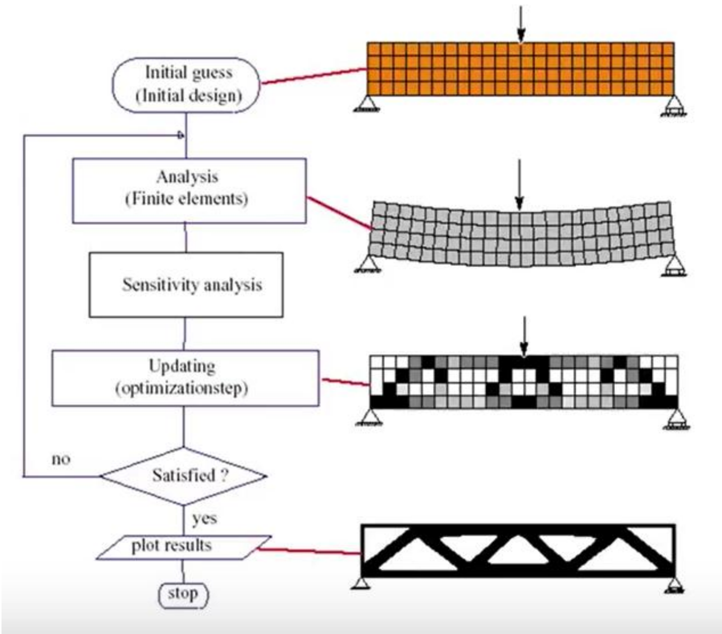


Figure 6. Topology Optimization software FEA

he macro approach proposed by (Li et al., 2003) with the Evolutionary Structural Optimization (ESO) method is a current method as an alternative method to the SIMP technique which focuses on removing materials from finite element analysis that have small stresses and deformations (under utilized) in the area design space.

3.2 Objective Function

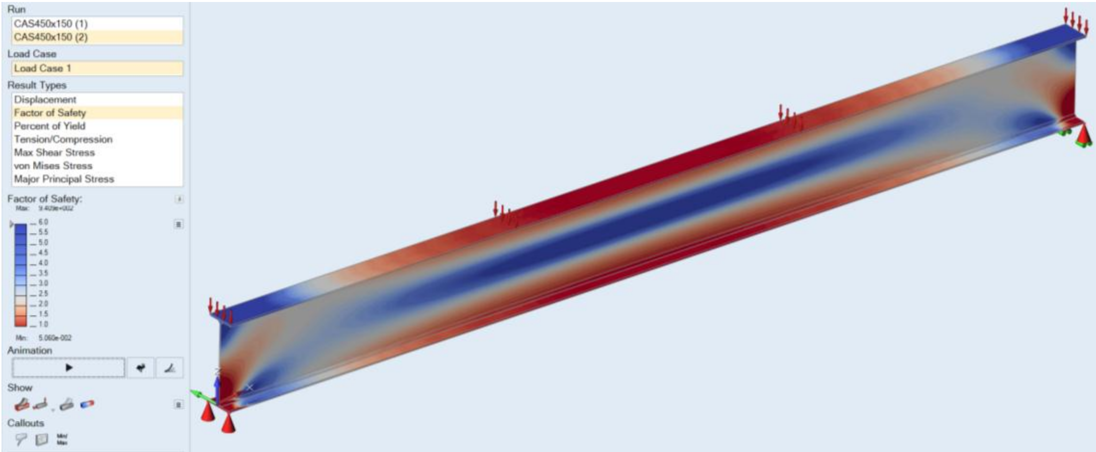
The Objective function of topology optimization is to minimize the weight or volume of Castellated IWF steel beam material by performing topological optimization based on the volume ratio, so that optimal stiffness is obtained.

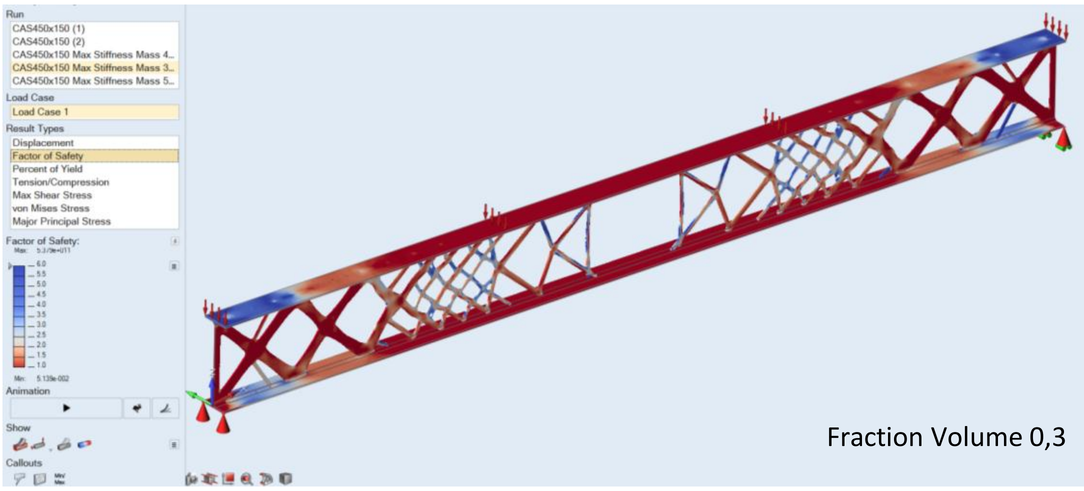
3.3 Constraint Function

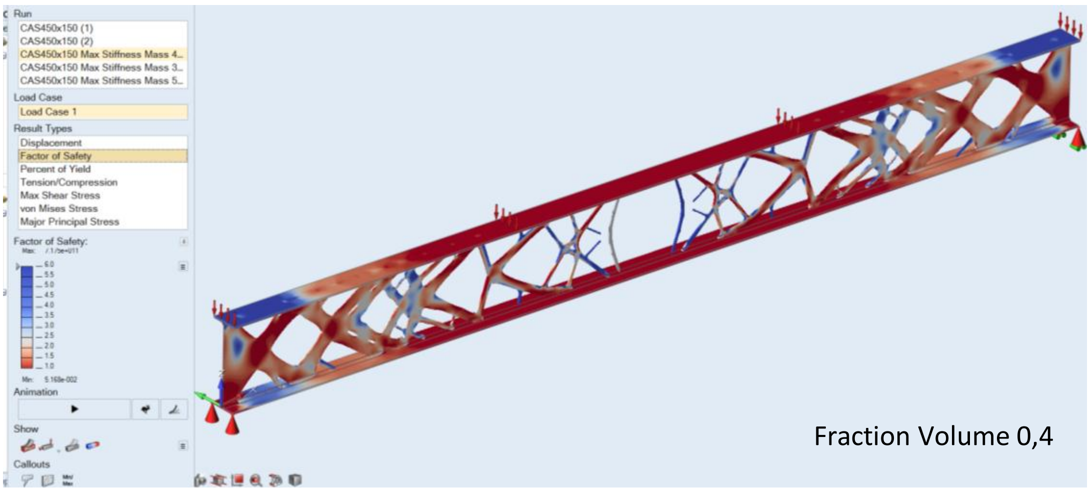
The constraint function of the topology optimization of the castellated IWF beam is the availability of material in the Indonesian market (the size of the steel profile used), the stress that occurs, the rigidity of the structure, the deformation of the structure as well as the production capability of manufacturing and the symmetrical layout in order to fulfill the objective function, by first doing the CAD modeling (Computer Aided Design) and FEA (Finite Element Analysis).

4. Results and Discussions

The results of the topology optimization analysis are explained by removing the element of the underutilized density layout area as shown on Figure.







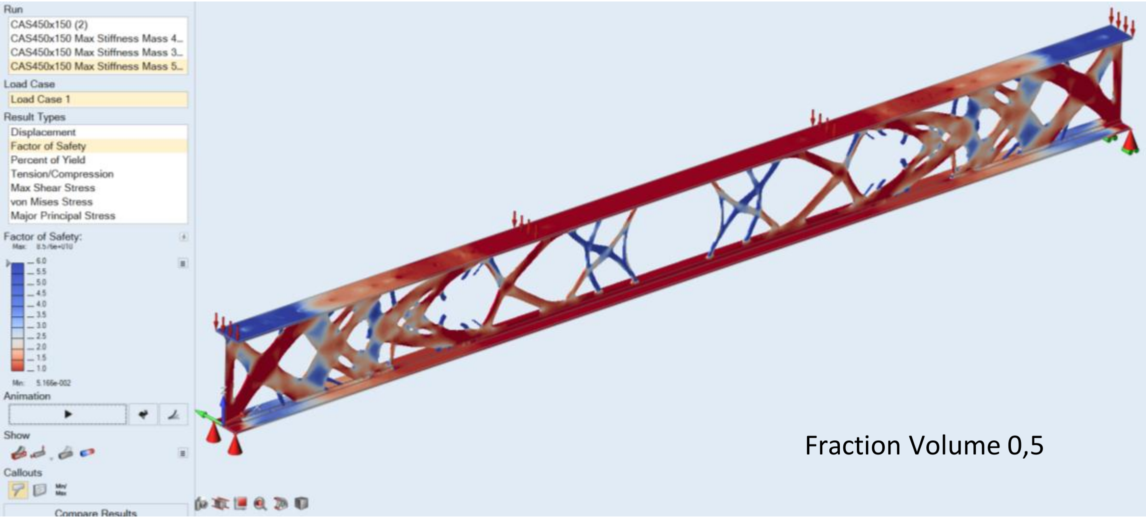


Figure 7. Topology Optimization Results of IWF 300x150x6.5x9 with some volume fraction constraints.

The density plot describes the optimal distribution of the material from the convergence of the optimization results. The red color shows the material's safety factor which is getting closer to the allowable stress (SF is close to 1.0) while the blue color has a large safety factor. When the dominant stress occurs in the flange position, then the body position (web) does not need material for the body position, the topology optimization also follows the stress - strain principle that occurs in the IWF body position. Topology optimization analysis brings great benefits in increasing intuition in engineering judgment, especially in the development of complex geometries. Topology analysis is also not limited to derivatives of practical designs that already exist in the manufacturing process.

Manufacturing issues are problems that should not be forgotten in topology optimization, therefore in conducting topology analysis it is necessary to pay attention to manufacturing constraints (Zhou et al., nd) including symmetrical, casting constraint, extrusion constraint and pattern graduation, this is so that the analysis results. Topology optimization can be done in industrial manufacturing processes. The symmetrical constraint that we use in the topology optimization analysis of the hollow beam, where the centerline that divides the X and Y axes is the same, the most optimal result is to use a volume fraction constraint of 0.4 as shown Figure .

The results of the next topology optimization analysis need to be smoothed by post-processing software so that a smoother CAD model can be obtained and manufacturing procedures for profile cuting and welding assembly techniques can be carried out after cutting.

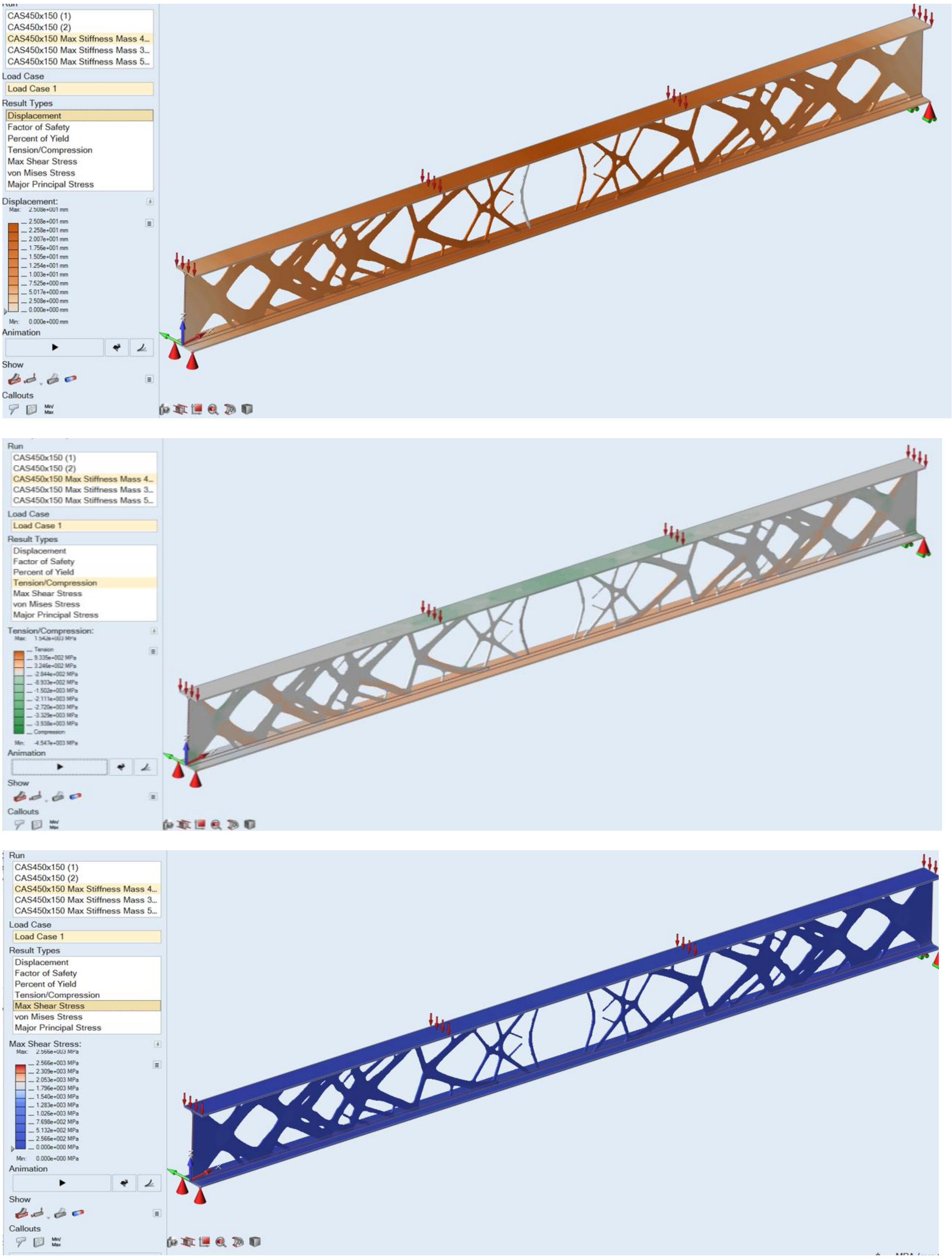
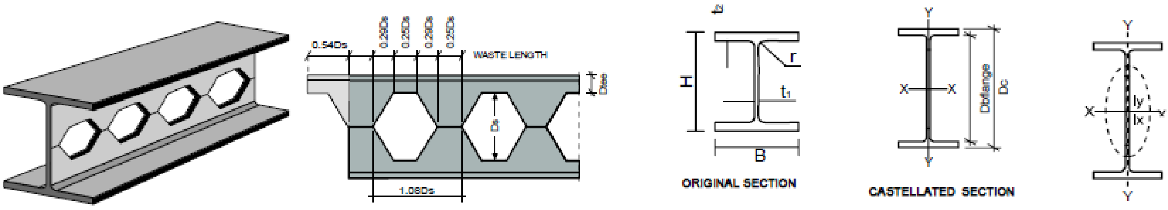


Figure 8. Shear Stress, Van Miss Stress and Deformation

5. Verification and Validation

In this research, it is focused on finding the pattern of layout, size of openings and number of openings using topology optimization more larger than compared with standard Castellated Beam PT. Gunung Garuda Product as show on figure 9.



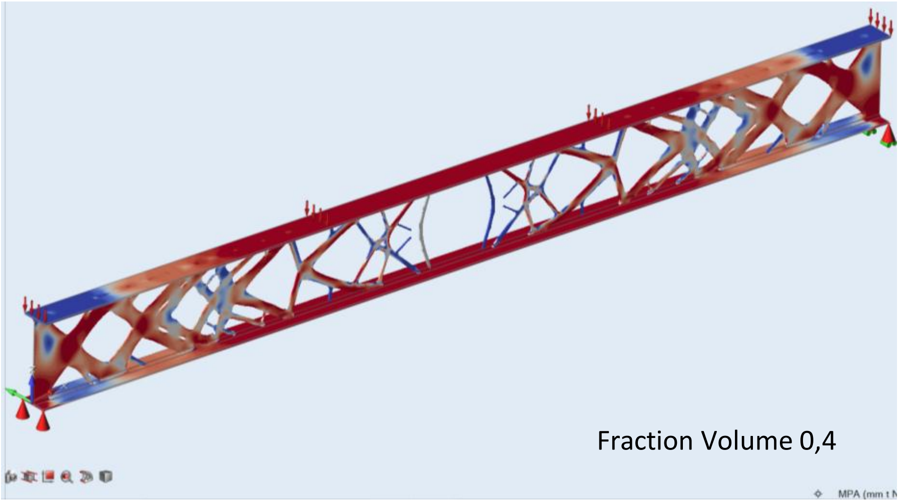


Figure 9. Validation Pattern FEA Topology Optimization Result with Castelated beam Product PT.Gunung Garuda

6. Conclusion and Suggestion

6.1 Conclusion

The results of topology optimization for a volume fraction of 0.4 with a beam span of 5m obtained a total weight of 154.3 kg, while the standard Castelated beam Product PT.Gunung Garuda total weight of 183.5 kg (36.7kg/m'), a saving of about 18.9%.

6.2 Suggestion

The layout form of the topological analysis has a rhombus opening which allows further research to be carried out to obtain large openings that are useful for HVAC systems.

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