

Behavior of Rail Ballast Layer Using Mortar Foam with LISA-FEA

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ABSTRACT

In the development of railroads, geosynthetics can be introduced in or under the stabilizer layer or sub ballast, foam mortar has become one of the trends in the construction sector in replacing the foundation layer as an excellent alternative. Researchers conducted a comparative analysis on railroad ballasts using a substitute for conventional railroad ballast, namely granular material and replaced with mortar foam, each material was modeled based on a typical standard rail track geometry using the same size and thickness, analyzed using software The finite element method is LISA FEA V.8 to get the values of the stresses that occur and the value of the decrease that occurs in the ballast with the two materials. From the results of the analysis of this study, it was found that there was an increase in the ability of ballast with mortar foam material compared to granular material, the decrease in stress that occurred and deformation in the deformation value in railroad construction gave an option to use conventional ballast substitutes. It can be seen that the decrease in ballast with granular material is 86.1 mm, while the foam mortar with 2000 kPa q_u is 0.022 mm. While the stresses that occur in the two ballast layers are explained as follows, in the ballast layer there is a stress of 38.09 N/mm² which is smaller than the result of the ballast layer with granular material, which is 104.73 N/mm².

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1. INTRODUCTION

It has been expressed that geosynthetics can give significant choices to further develop track support adjustment what's more, in this way lessen track support costs and working expenses. In railroad development, geosynthetics can be introduced inside or under a layer of stabilizer or subballast [1]. Ballast degradation and the resulting deterioration of the track geometry [2].

The use of mortar foam has become one of the trends in the construction sector in replacing the top layer of foundation as an excellent alternative. Mortar foam has a low thickness and great usefulness, which has been generally utilized in development applications [3].

In analyzing the behavior of elements, LISA FEA V.8 can provide excellent information in determining the stress values that occur in the elements reviewed linearly and nonlinearly [4]. Apart from model validation, the application of this model in engineering practice, such as vehicle-induced vibrations from continuous welding rail (CWR), has been revealed, and several conclusions are drawn from numerical studies [5] [27].

In this study, researchers conducted a comparative analysis on railroad ballast by using a substitute for conventional railroad ballast materials, namely granular materials with specifications that have been regulated in the regulation of the minister of transportation republic of Indonesia PM number. 60-2012

About technical requirements for railways, by using mortar foam, a review of the stresses that occur and the value of the decrease that occurs in ballasts using mortar foam. The Kedaton Bridge abutments use a lightweight material mortar foam with a density (ρ) = 0.6 t/m³ for strength (q_u) = 800 kPa and density (ρ) = 0.8 t/m³ for strength (q_u) = 2000 kPa. It was built through a full-scale test of the R&D program of the 2009 FYP Pusjatan with an embankment thickness of 3.85 m. The condition of the Kedaton Bridge with light materials after 3 years post-construction, shows that there is almost no road subsidence (< 1 mm) and there has never been a road pavement overlay [6].

It is hoped that this research will provide a good repertoire and contribution to the world of railways, especially on ballast elements which are part of the railroad and provide excellent carrying capacity for railroad construction.

2. RESEARCH METHOD

In this study, the author will make a typical model of railroad construction, using conventional materials, namely granular materials and mortar foam materials.

The ballast modeling will use finite element analysis software LISA FEA V.8 to perform model analysis on the 2 railroad ballast materials, namely using granular material and using mortar foam material, with a typical image as in Figure 1.

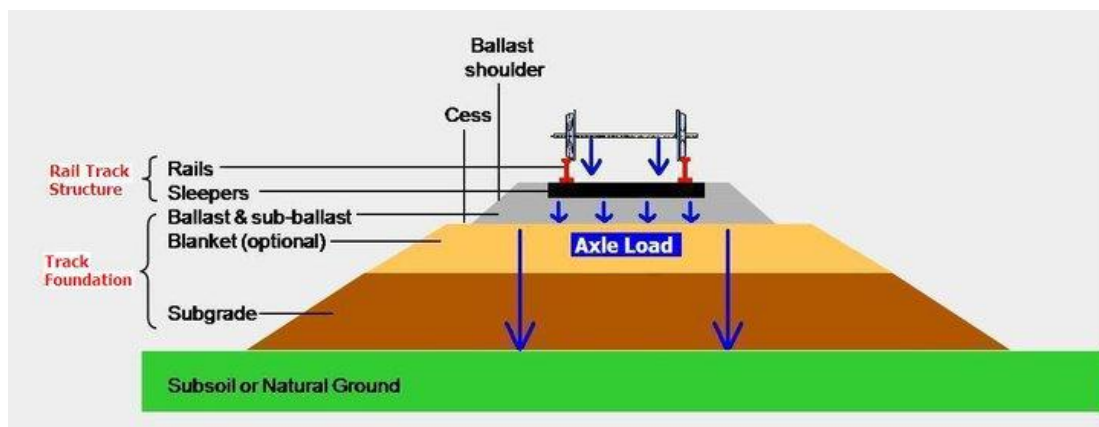


Figure 1. Typical of rail track

2.1 Ballast Railroad

The ballast layer is basically a continuation of the subgrade layer and is located in the area where the stress concentration is greatest due to train traffic on the rail road, therefore material its constituents must be highly selected. The main function of ballast is to transmit and spread the load bearing to the subgrade, fixing the bearing position and pass water so that there is no puddle of water around the bearing and rails.

Ballast forming material must meet the following requirements:

1. The ballast must consist of crushed stone (25 – 60) mm and have good resistance capacity, high friction resistance and easy to compact.
2. Ballast material must be multi-angled and sharp.
3. Maximum porosity 3%.
4. Maximum average compressive strength 1000 kg/cm²;
5. Minimum specific gravity 2.6;
6. Maximum soil, silt and organic content of 0.5%;
7. Maximum oil content 0.2%;
8. The ballast according to the Los Angeles test should not be more than 25%

The material for the embankment must be easily compacted, stable against the load from the train, rainfall and earthquakes and must also be free from subsidence. excessive. The top of the embankment with a minimum thickness of 1 m must be of better material than the bottom of the embankment. At the foot of the slope of the road body there must be a width of at least 1.50 m and the surface has a slope of 5%. Construction of the railroad in the excavated area if the railroad is in excavated or original soil, then the type of subgrade may not be classified as unstable/stable soil low. The subgrade must be located at least 0.75 m above the highest ground water level. If the excavation depth is greater than 10 m, then at every 6 m depth, a 1.50 m wide “berm” must be made. The subgrade must be able to carry the subgrade and be free from settlement problems. If there is a layer of soft alluvial fine-grained soil with an N-SPT value of 4, then it must not be included in the 3 m layer measured from the road formation surface under any conditions. The bearing capacity of the subgrade determined by a certain method, such as ASTM D 1196 (Test load plate using a 30 cm diameter bearing plate) must not be less than 70 MN/m² on the surface of the foundation soil of the excavated area [7].



Figure 2. Granular material rail ballast

2.2 Mortar foam

Mortar foam is concrete that contains heavy aggregate volume equilibrium density, between 1140 and 1840 kg/m³. The advantages of concrete is able to withstand compressive forces well, and has properties that are resistant to corrosion and decay by environmental conditions, fresh concrete can be easily molded as desired, the mold can also be used repeatedly so it is more economical, fresh concrete can be sprayed on the cracked surface of the old concrete or can be filled into the cracked concrete in the repair process, fresh concrete can be pumped making it possible to pour in places where the position is difficult, and concrete is wear-resistant and fire-resistant, so maintenance is less expensive. Composite material consisting of a mixture of foaming agent (foam liquid), cement, sand and water [6] [8].



Figure 3. (a) Lightweight formation in mixer machine (b) Mortar foam

The 28 days compressive strength of specimens prepared utilizing nearby cleanser differed from 4.07-4.82 MPa. It is to be seen that all the detergent mix designs delivered in this exploration work yielded a compressive strength well over the base prerequisite of 1.38 MPa set forward by ASTM Specifications C796-04 and C 869-91. As set thickness of examples arranged utilizing local detergent changed from 865-960 kg/m³ [9].

Compressive strength based on (ASTM C39/C39M)

Table 1. Compressive strength and splitting tensile strength requirements

Calculated equilibrium density maks, kg/m ³ (lb/ft ³)	Average 28-days splitting tensile strength min, MPa(psi)	Average 28-days compressive strength min, MPa(psi)
All lightweight aggregate		
1 760 (110)	2.2 (319.083)	28 (4061.06)
1 680 (105)	2.1 (304.579)	21 (3045.79)
1 600 (100)	2.0 (290.075)	17 (2465.64)
Combination of normal weight and lightweight aggregates		
1 840 (115)	2.3 (333.587)	28 (4061.06)
1 760 (110)	2.1 (304.579)	21 (3045.79)
1 680 (105)	2.1 (304.579)	17 (2465.64)

Source: SNI 2461:2014

2.3 Typical Railroad

As for the cross-section of the railroad track used is a railroad cross-section with a width of 1435 mm with a road class of type 1 with a maximum speed (V max) of 120 km/hour with the following geometry parameters:

- d1 = 3000 mm
- b = 1500 mm
- C = 2350 mm
- k1 = 2650 mm
- d2 = 500 mm
- k2 = 3750 mm

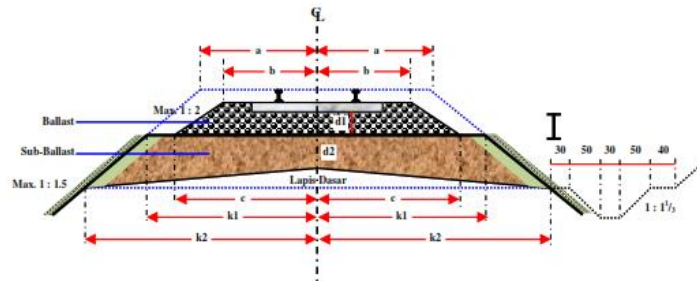


Figure 4. Cross section of railroad in straight section (Railway width 1435 mm)

The modeling on the LISA V.8 software is shown in Figure 5 by adjusting the data listed above with the value of the land parameter in accordance with the technical requirements of the railway line issued by the Indonesian government.

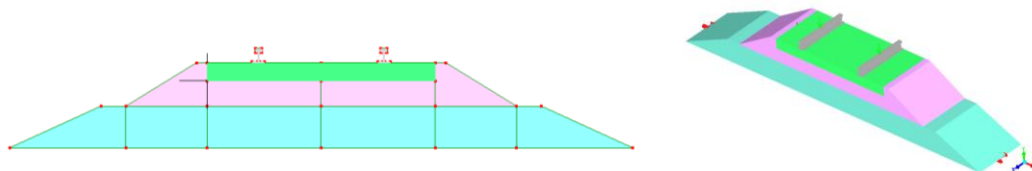


Figure 5. Modeling in FEA software

2.4 Finite element method (FEM)

The finite element method (FEM) is a mathematical technique for taking care of specialized examination issues. The limited component strategy consolidates a few numerical ideas to create conditions of a straight or nonlinear framework. The quantity of conditions created is typically extremely huge, arriving at in excess of 20,000 conditions. Hence, this strategy is of minimal down to earth esteem except if a reasonable PC is utilized.

The finite element method uses an utilizes a component discretization way to deal with tackle the issue of tracking down relocations of vertices/associations/grids and primary powers. Discrete component conditions are connected with the lattice technique for primary examination and the outcomes got are indistinguishable from those of traditional investigation for structures. The discretization should be possible with one-layered components (line components), two-layered (plane components) or three-layered (volume/continuum components). This approach utilizes a continuum component to decide an answer that is nearer to reality [5], [10][17].

2.5 LISA

LISA, a well known limited component examination application, was utilized to gauge the temperature climb for three distinct models of intensity exchangers. The three sorts of models are, arranged by their straightforwardness and simplicity of development, the line component model, the shell model, and the strong model.

For line component models just, the convection coefficient of the baseplate surface not set in stone as a portion of the worth utilized somewhere else since we can't bar convection from gathering the baseplate surface with the face determination device. It's simply a question of presence of mind.

For the other two models, it's not difficult to prohibit the mounting surface from convection - we simply don't choose that surface. An inner intensity generator is utilized for each situation, and the volume of the whole floor piece is thought to be the intensity source. Care ought to be taken while applying limit conditions to a line component model [18] to [26].

3. RESULTS AND DISCUSSION

In this study, researchers compared the stresses that occur in railroad construction with ballast types using granular materials by replacing the material using foam mortar/mortar foam, where the replacement of this material is only on the ballast section while for the sub ballast section it remains using materials that have been required in the regulations for the technical requirements of the railway line.

Table 1. Material Properties

No.	Material	Young Modulus (N/mm ²)	Density (N/mm ³)	Poison Ratio
1	Steel (Rail)	210,000.00	0.00007850	0.30
2	Concrete fc' 45 MPa (Sleepers)	31,528.56	0.00002400	0.20
3	Ballast (Granular)	150	0.00002000	0.35
4	Sub Ballast (Clay)	75	0.00001800	0.25
5	Ballast (Mortar Foam 2000 kPa)	2.00	0.00001000	0.19
6	Sub Ballast (Mortar Foam 800 kPa)	0.80	0.00000800	0.19

3.1 Stress Behavior of Ballast with Granular Material

The load used in this study is a concentrated load on one axle according to the 1921 (RM21) plan loading scheme of 20 tons or 200000 N, and works as wide as the rail surface is 74.3 mm so that the load is evenly distributed on the rail surface is 2691, 79 N/mm.

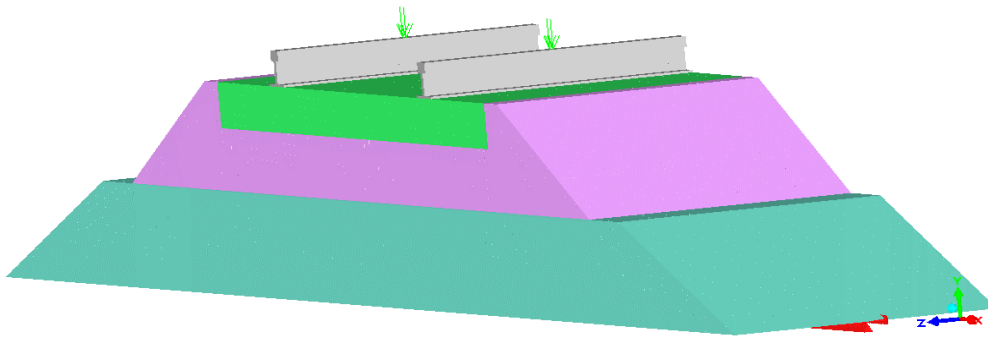


Figure 6. Modeling in FEA software

The bearing material from the railroad tracks uses concrete material with $f_c' 45 \text{ MPa}$ in accordance with the minimum quality provisions for railroad sleepers, after being given a load on the rail surface of 2691.79 N/mm then the value of the decrease that occurs at the ballast position is 86.06 mm < from the required 100 mm as shown in Figure 7(a) for the largest settlement position in the ballast layer. While the decrease that occurred in the sub ballast was 66.003 mm , still smaller than the decrease that occurred in the ballast and the specified conditions, as shown in Figure 7(b).

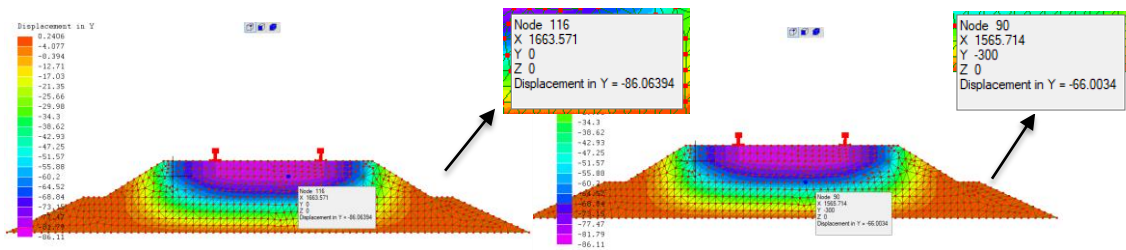


Figure 7. Modeling in FEA software- ballast with granular material

While the stress that occurs in the ballast layer with granular material is shown in Figure 8(a) which is 104.73 N/mm^2 . And in the sub ballast position with the selected embankment soil material, a stress occurs as shown in Figure 8(b) which is 10.043 N/mm^2 .

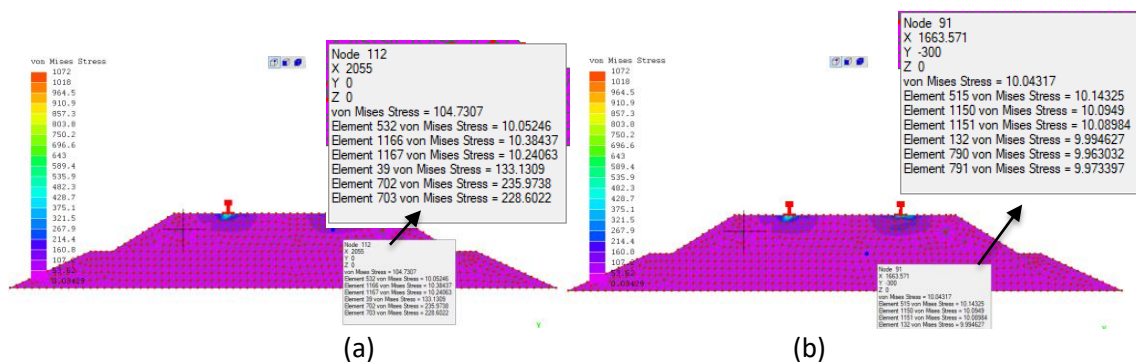


Figure 8. Granular material (a) the stress that occurs in the ballast layer (b) the stress that occurs in the sub ballast layer

3.2 Stress Behavior of Ballast with Mortar Foam Material

In this ballast and sub-ballast material, mortar foam material is used with different capacities, where the ballast layer uses foam mortar with $q_u=2000 \text{ kPa}$ and foam mortar on the sub-ballast layer uses foam mortar

$q_u=800$ kPa. And there is a stress when the load is applied to the rail surface according to the granular material, which is 2691, 79 N/mm. The deformation value that occurs in the ballast layer as shown in Figure 9(a) is 0.02247 mm. while the decrease that occurs in the sub ballast layer occurs as shown in Figure 9 (b) which is 0.0140 mm.

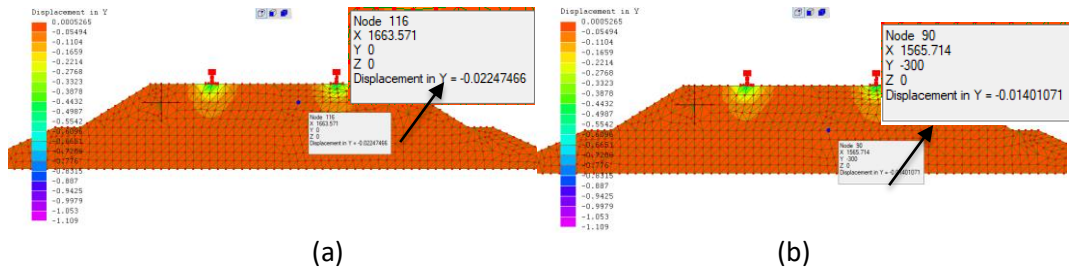


Figure 9. Mortar foam material (a) deformation in the ballast layer (b) deformation in the sub ballast layer

While the stresses that occur in the two ballast layers are described as follows, in the ballast layer there is a stress of 38.09 N/mm² which is smaller than the results of the ballast layer with granular material, which is 104.73 N/mm², as shown in Figure 9(a), while in the ballast layer, it is shown in Figure 9(a). the sub ballast stress occurs at 9.87 N/mm² where the result is smaller than the result of the sub-ballast stress with grained material, which is 10.04 N/mm², as shown in Figure 9(b).

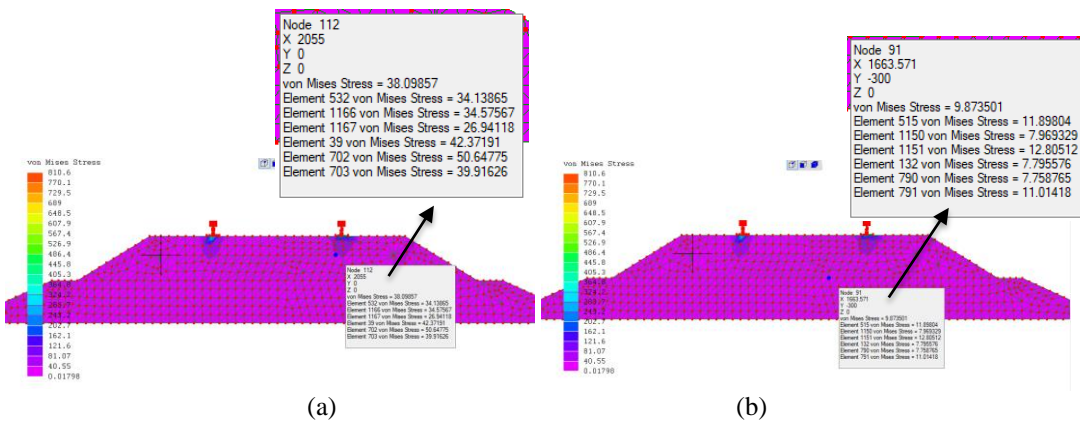


Figure 10. Mortar foam material (a) the stress that occurs in the ballast layer (b) the stress that occurs in the sub ballast layer

4. CONCLUSION

From the results of the analysis of this study, it was found that there was an increase in the ability of ballast with mortar foam material compared to granular material, the stress deformation that occurred and the deformation of the deformation value in the construction of railroad tracks gave an option to use conventional ballast substitutes. It can be seen that the decrease in ballast with granular material is 86.1 mm, while the foam mortar with 2000 kPa q_u is 0.022 mm. While the stresses that occur in the two ballast layers are explained as follows, in the ballast layer there is a stress of 38.09 N/mm² which is smaller than the result of the ballast layer with granular material, which is 104.73 N/mm². This research needs to be continued by conducting experimental tests to provide information and validate the results of numerical tests, especially regarding loading options, types of typical rails and some very broad options to be re-examined.

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