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DEFORMATION EFFECTS ON STRUCTURAL INTEGRITY AND OPERATIONAL SAFETY IN RAIL ROUTE SYSTEMS: A COMPUTATIONAL STUDY

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Abstract:

The present research identifies railway track deformation as a major issue in terms of structural integrity and operational safety. However, the existing literature indicates that traditional track design approaches are not sufficient enough hence the need for more sophisticated computational tools. One possible innovation to overcome this problem is to adopt the deformation in the railway track approach using ANSYS Software (DRT-AS). However, ANSYS helps simulate different loads on railway tracks via DRT-AS creating a virtual model of how actual models behave in terms of deformations using comprehensive numerical analysis. Also, unlike other methods that forecast, this method offers an accurate description of real track behavior under various conditions. This article provides results from an experimental study that has been successfully conducted through the DRT-AS process thereby enabling identification of key affected areas and suggesting appropriate modifications in design. Other performance indicators include stress distribution, strain patterns, and overall structure stability among others. In addition, it is worth emphasizing that the paper pays much attention to the efficiency and dependability of DRT-AS through a detailed examination which must be accompanied by its merits and demerits with regard to the treatment of deformations within railway track I-sections. Combining the suggested DRT-AS technique with ANSYS software provides strong tools that promote robust rail transport systems making them structurally stronger than before. This present analysis represents a significant milestone towards a better understanding and control over deformation problems involving railway track design.

Keywords: Railway track, I-section, deformation, ANSYS software.

1. INTRODUCTION:

Railways play important roles in the economy of any country since they form the backbone of any nation's transport system [1]. This industry is so dynamic that there are constant improvements being made to meet these growing demands [2]. These advancements lie in controlling rolling contact between train wheels as well as rails relying on variables like speeds at which trains move, weights carried by them, wheel-rail profiles as well as reactions emanating from sections of tracks [3]. Trains typically need some sort of structure referred to as the railway track for smooth operations, which is made up of substructure and superstructure [4]. Technological complexity includes a ballast, sub-ballast, sleepers, fastenings, rails, and rail pads. The level of complexity that contributes to the overall stability and performance of railway tracks makes them be divided into various components including substructure and superstructure [5]. To support the base there is an arrangement layer with a ground forming part of the substructure. However, superstructures are composed of moving train elements like rails that have been attached to sleepers as well as stabilizers or sub-ballasts [6]. The distribution of mechanical stress is important in predicting failures and evaluating safety aspects. Different external parameters that alter the rolling contact between rails and wheels generate dynamic pressures, which spread stresses throughout the track system [7]. For rail tracks to be long-lasting and functional, it is necessary to know how each part of them absorbs and dissipates strain. In view of improving rail systems for future needs, mechanical stress distribution analysis becomes imperative [8]. This review aims at contributing knowledge on mechanical stress distribution in railway tracks by considering train speed, loads as well as track components. This study seeks to explain how the interaction between substructure and superstructure elements affects the operation of a railway transportation system with reference to design, maintenance, and safety standards. The present study will numerically analyze deformation in an I-section of railway tracks using ANSYS software with a focus on designing according to constantly changing requirements [9]. The findings from this research emphasize why there is such an urgent need to understand how mechanical stress spreads in a railroad for its safety and soundness. In terms of deformation issues, the DRT-AS technique easily tackles them thus smoothly transferring them into perfectly matched categories within which various types of railway track constructions fall [10]. Consequently, this computational study uses ANSYS software for simulating different loading situations while analyzing I-section deformation behavior to come up with stress patterns. Ballasted railway track substructures are under more stress and deformation due to quicker and heavier trains in public transit. Track damage and derailment dangers need a detailed study of ballasted railway track–ground system dynamic response [11]. To investigate stress transmission and track deflections under different train-track-ground situations, this current research uses a complex three-dimensional finite element model (3D-FEM) to describe actual train movement loads. Track substructure layer modulus and thickness, train speed, train moving load amplitude, and other factors have been considered. For railway engineers facing newer, quicker, and heavier train traffic, the present research recommends optimum design schemes and lifetime maintenance procedures for ballasted railway tracks. This present article reports two novel asphalt trackbed concepts: the D-WHRAM trackbed and the DREAM trackbed, which combine dry-mixed rubberized asphalt with wet asphalt. The proposed trackbed's dynamic response and design parameters has been evaluated by numerical analysis using a three-dimensional finite element model in ABAQUS software [12]. The primary research objectives are to Prepare Asphalt Mixture Cuboid (PAMC) samples of varied widths and thicknesses. Analyses of vertical dynamic compressive stress, acceleration, deformation, tensile strain, and the process of compressive stress development within the subgrade gain insights. Findings show that width and thickness are the best characteristics for both trackbeds. The PAMCs have comparable maximum compressive stress values despite their varied material compositions. The increased crumb rubber component of the DREAM trackbed causes it to display more dynamic deformation than the D-WHRAM trackbed. The railway's mountain tunnel that cuts through a huge karst cave is the subject of this investigation. Difficulties, such as varying collapse accumulation thickness, were presented by the cave's height below the tunnel route. Following extensive evaluation, the decision was made to fill the karst cave using cave ballast backfill and higher grouting as the solution for the superthick backfill subgrade [13]. Conducting dynamically scaled model tests on a high-speed railway subgrade dynamic test platform allowed for considering possible vibrations and dynamic settlements during train operations. Train speed and subgrade slab thickness were among the parameters that were modified. The results showed that the dynamic response decreased rapidly with increasing subgrade slab thickness, indicating a drop in average acceleration at the subgrade slab base. The main value of this article is that it suggests a means to build railways through massive caverns that don't break the bank. It also provides useful information for future projects and helps advance transportation sector building technologies. The primary objective of this present research has to provide a framework for assessing the extent to which railway dams and other vital national infrastructure had been damaged by liquefaction. The research created a three-tiered risk assessment system—no harm, caution, and critical—to examine the railroad design and maintenance requirements [14]. The evaluation considered lateral displacement, residual settlement, and vertical irregularity. A dynamic numerical analysis using a finite difference technique (FDM) and three simplified evaluation approaches has been proposed for evaluating damage caused by liquefaction. The Honam high-speed line served as a test bed for the practicality of these approaches. The results showed a tendency for the associated standards to overestimate settlement values and for the dynamic numerical analysis approach to underestimate them. To help increase the resilience and safety of infrastructure, this present study offers a thorough technique for assessing the risk of liquefaction-induced damage to railway embankments. The primary emphasis of this article is the need for a well-maintained network of railway tracks that can withstand the enormous vibrations and deformations caused by high-speed trains, particularly those carrying freight. The study uses geosynthetic-reinforced embankments for fill sections where rails are normally installed, with or without retaining walls [15]. A moving load study is carried out on a ballasted rail track positioned across various geometries of synthetically reinforced embankments using

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elastoplastic material models (EMM) with material damping and infinite limits. A pressure-loaded areal patch models the load's constant-speed motion in semi-high and high-speed scenarios. Using estimated building costs as a metric, the present research assesses how different reinforcing agents affect fill section layouts. The lateral and vertical dynamics of the moving load has been studied. The results emphasize the potential of geosynthetics and facing walls to reduce ground acceleration within the speed range, which might improve railway track performance and reduce vibrations.

2. OBJECTIVES OF PRESENT RESEARCH WORK:

The following are the main objectives of the present research work:

- Adequate knowledge of wagon dynamics including train speeds and loading conditions influences track management decisions.
- Advanced DRT-AS through ANSYS I-section deformation analysis on substructure & superstructure components helping critical deformation area identification.
- Rail safety improvement through addressing deformation concerns so that mechanical stress distribution optimization and track design changes will minimize defects.

3. NUMERICAL METHODOLOGY:

In designing and analyzing railway tracks, various software tools are vital. For computer-aided design (CAD) software, Pro/ENGINEER (Pro-E), presently known as PTC Creo, is a leading three-dimensional package that offers extensive capabilities for engineering and product design creation. This present article reveals the importance of Pro-E function in the early phases of design whereas the subsequent interoperability with ANSYS is elucidated. Initial Graphics Exchange Specification (IGES) is a standardized file format which enables seamless data sharing between computer aided design (CAD) systems. The method involves exporting the railway track design from pro-e to IGES format.The IGES format allows more comprehensive numerical analysis by reading it into ANSYS after converting it.

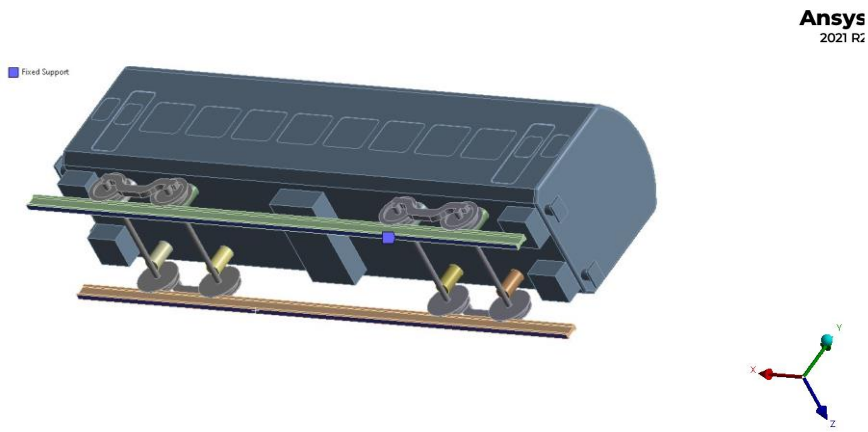

Figure 1: Illustration of the fixed support design.

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For numerical simulations such as finite element analysis (FEA), the term "meshing" refers to the process of "meshing" in numerical simulations such as finite element analysis (FEA), which means that geometry has been divided into finite elements. This process is very important at this stage. 1 lakh iterations means that meshing took plenty of refinement in that direction. It therefore helps to conduct precise meshing iterations when investigating deformations in I-beam cross-sections accurately and trustworthily through numerical analysis of railway tracks. By exporting Pro-E designs smoothly in IGES and importing them fully into ANSYS for a complete number crunch based on long meshing iterations, engineers understand deformation patterns and structural behavior of a rail track section I.; Thus making progress towards more accurate visualization of what happens to the track under different loads conditions which will eventually lead to better decisions made regarding changes and improvements in designs. Answers provide all-inclusive approaches for designing and numerically analyzing railway track deformation combining their potentials to solve difficult issues associated with structural integrity and safety of railways. In other words, this implies that there has been consideration about everything.

$$W_{bc} = \frac{y_c - y_b}{\|y_b - y_c\|_2} + (B_b\_B_C) \tag{1}$$

Equation (1) estimates the angle among y_c and y_b and the vector W_{bc} that connects y_c and y_b. When the structure in the area is curved, the nearby super voxels $(B_b\_B_C)$ are referred to as strongly connected. The angle between y_c and y_b as well as the vector W_{bc} that connects B_b and $B_C$is calculated.

$$BN = \frac{\sum_{u=1}^{m} y_c(bj)}{B_b} + \frac{\sum_{u=1}^{n} y_c(cj)}{B_b} \tag{2}$$

From the above-inclined equation (2) above, b and c are used to calculate the amount of angle inclination, j is used to calculate tangible activity, m is used to represent the total number of issues, and n is used to denote the total amount of compliance at time u. $\frac{\sum_{t=1}^{n} y_c(cj)}{B_b}$ and $\frac{\sum_{u=1}^{m} y_c(bj)}{B_b}$ a selected as the adherence measurement BN to assess the framework's feasibility using summation with limits with respect to time $u = 1$.

$$BRu(s) = \sum_{s=1}^{\infty} X_s * gt \frac{W_{cd}}{\sum_{j=1}^{xm} W_{bc}} + n_p \tag{3}$$

The quantity gt of the resources s that are available such as the number of workers $Ru(s)$, mortar pumps n_p, and false ceilings gt equipment is stated in the constraint-based modeling system shown in above equation (3) by applying summation. The same operations, limitations, and components are employed across these modeling runs.

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The thorough method for designing railway tracks and performing numerical analyses using Pro-E and ANSYS software incorporates Figure 1 which delinates the design of fixed support. The planning of the fixed support takes on paramount significance within the framework of the planned investigation into the deformation analysis of the railway track I-segment. Railway tracks structural stability and integrity are closely related to fixed support arrangements. When used during the early phases of design, Pro-E guarantees an accurate representation of the fixed support in the digital model. After that, exporting to IGES format allows for easy integration into ANSYS for further numerical analysis. ANSYS environment is essential for describing and evaluating the support conditions, which helps to understand how the fixed support affects the railway track's deformation patterns. Implementing Pro-E and ANSYS to design and evaluate the fixed support is crucial to enhancing the track's structural performance and safety. Figure 2 explains the appropriate modeling of the gravitational forces operating on the system in the context of railway track design and numerical analysis requires incorporating the standard earth gravity of 9806.6 mm/s². A crucial part of structural analysis, particularly in dynamic simulations where forces affect the behavior of railway tracks, is the gravitational force, often expressed as 9.806 m/s². This guarantees an accurate response of the track towards gravitational forces when these gravitational components are included within the numerical analysis based on ANSYS software. Standard earth gravity provides consistent predictions for both deformations at a track and its structural behavior. In summary, it is essential to eliminate the standard earth gravity components while performing a numerical analysis of the impact of gravitational forces on railway tracks. Railway track numerical analysis with ANSYS software has become enjoyable by integrating conventional earth gravity components. The selected equivalent elastic strain in the static structural analysis, measured in mm/mm, further improves the simulation's accuracy. It shows how materials on the track respond to applied forces by showing deformation with respect to the original length in millimeters per millimeter strained.

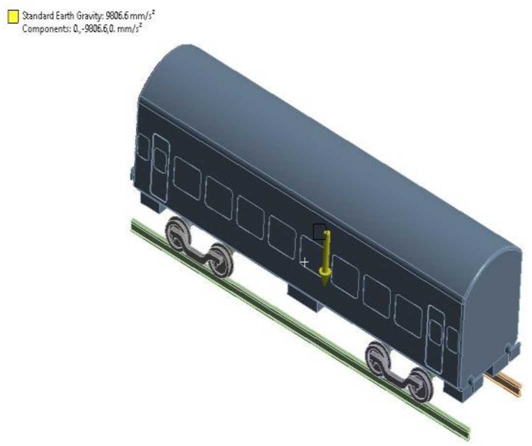

Figure 2: *Visualization of Standard Gravitational Acceleration.*

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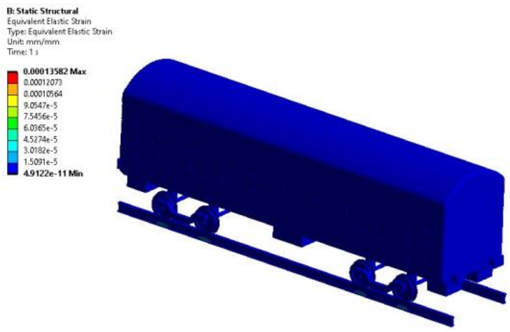

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Figure 3: *Analysis of Equivalent Elastic Strain.*

Integrating conventional earth gravity components with the details of static structural analysis is a pleasure in the world of railway track numerical analysis utilizing ANSYS software. The selected equivalent elastic strain in the static structural analysis, measured in mm/mm, further improves the simulation's accuracy. Strain, measured in millimeters per millimeter, provides light on the track materials' response to applied forces by showing deformation relative to the original length. The static structural analysis has a time parameter of 1 s, which implies quasi-static analysis whereby the impacts of inertia are less significant than those of the applied loads. This is how rails usually behave under stationary gravity stresses. The strain values between 4.9122e-11 and 0.00013582 indicate how the deformations of the track elements happen to be. Thus these numbers explain the strain distribution over a structure and give information about its material response to stress as well as the effects of earth's gravity on them. Through traditional terrestrial gravitation and static structural properties, railway track behavior can be thoroughly examined to allow for informed design changes or improvements.

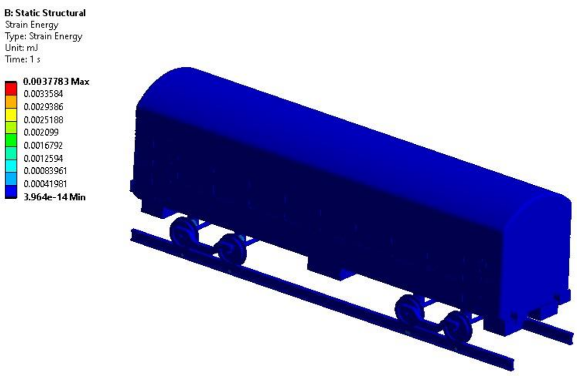

Figure 4: *Distribution of Strain Energy.*

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Figure 4 shows ANSYS software-based numerical analysis of rail track with conventional earth gravity components that are associated with specific parameters in this type of static structural analysis. In addition, using strain energy as the preferred type in static structural analysis helps us better understand how structures react to stresses carried by them (Ghosh et al., 1996). Strain energy is essentially useful for measuring potential energy stored by a material due to deformation (Hankinson et al., 2007). To make it consistent with the case under study, it is quantified in mJ. In cases when inertial effects are negligible relative to applied loads, namely at 1 second quasi-static analysis emphasizes the state of rest from an equilibrium position under consideration. This option renders adequately what happens when all other external forces have been removed except gravitational pull towards a planet. It indicates how internally distributed strain energy varies within a track structure ranging from 3.964e-14 through 0.0037783 units. These estimates help in assessing overall performance by showing where materials store and release mechanical work during deformation (Timoshenko et al., 1934). By incorporating typical terrestrial gravitation and plastic deformation properties into their models, they could ultimately provide comprehensive details about what is actually going on in rail tracks under static loading conditions. For such reasons, it is pertinent to have this information for tracking strength and safety during the planning of design upgrades or changes when subjected to static loadings.

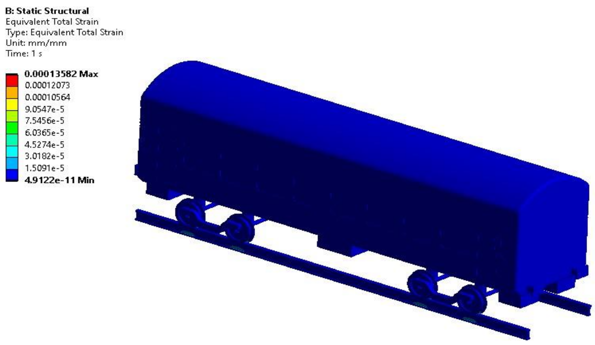

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Figure 5: *Analysis of Equivalent Total Strain.*

The inclusion of conventional earth gravity components allows the static structural analysis details to align perfectly with all aspects of ANSYS software used for the numerical analysis of railway tracks. In a static structural analysis, an accurate and detailed deformation measurement can be done using equivalent total strain as the preferred type; whereby its units are mm/mm (Timoshenko et al., 1934). The total equivalent strain comprises all deformations that happen in a track including plastic and elastic portions (Ghosh et al., 1996). This dimensionless ratio represents strain which is basically the change in length divided by length in millimetres per millimetre. The quasi-static analysis reveals the static equilibrium condition within which inertial effects are negligible in comparison with applied loads, indicated by a

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time parameter of 1 second. For testing how well the track resists gravity while static, this selection is ideal. These observed values for total equivalent strain between 4.9122e-11 and 0.00013582 give insight into the overall deformation that has occurred in the rail structure as it strains. These numbers represent the strain distribution across the structure and are thus significant in determining how materials respond to stresses, especially under gravitational force. To achieve an elaborate study on railway track behavior, standard earth gravity needs to be included and analyzed using specific parameters containing comparable total strains in a static structural context. This information contributes to a comprehensive understanding of the track's structural performance and safety during static loading conditions as such informed decisions can be made regarding design modifications or improvements. Designing and evaluating railway lines requires advanced software. Three-dimensional CAD software Pro/ENGINEER (Pro-E), now PTC Creo, is used for engineering and product design. Its importance in early design and compatibility with ANSYS is vital for numerical analysis. Pro-E and ANSYS can share data easily via IGES, enabling thorough numerical analysis. Pro-E accurately represents fixed support, and ANSYS allows in-depth analysis. Fixed support design is crucial to structural stability. Dynamics need gravity, thus typical earth gravity is used. Predicting the track's reaction to loads requires this knowledge. Static structural analysis examines deformation patterns, energy distribution, and overall deformation using equivalent elastic strain, strain energy, and equivalent total strain. These studies and ordinary earth gravity help explain the track's structural performance and safety under various loading scenarios.

4. RESULT AND DISCUSSION:

To guarantee structural integrity and operational safety, it is crucial to analyze how a railway track responds to different loads numerically. In this research, ANSYS software is used to do simulations, emphasizing important track behavior elements such as equivalent total strain, strain energy, equivalent elastic strain, and standard earth gravity. The provided data shed light on the behavior of the railway track I-section under various circumstances. Modifications to the design, maintenance procedures, and improvements to track safety may be better determined using this data.

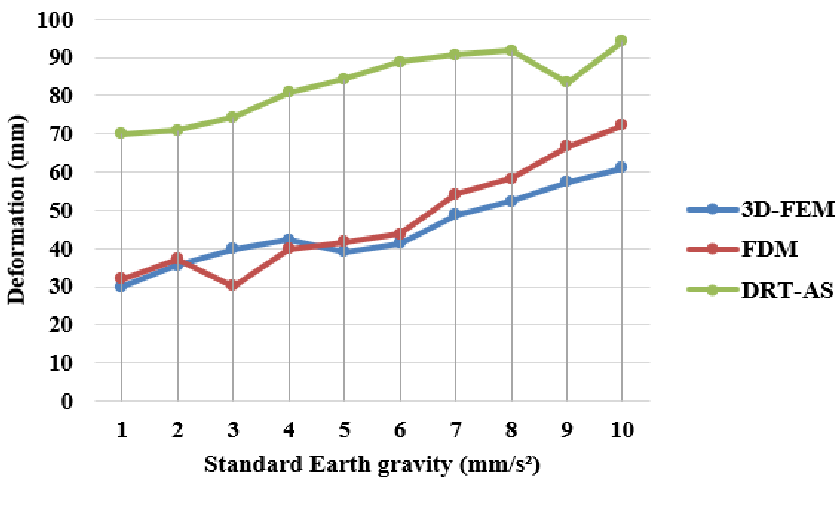

Figure 6: *Illustration of Standard earth gravity (mm/s^2) with respect to derformation (mm).*

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The equation (4), the standard earth gravity SEG is shown below:

$$SEG = \frac{Mg^2}{\omega(f_n l_x)} + \alpha\tau(n-1) \quad (4)$$

To fully analyze the track's response to gravitational forces Mg^2, engineers may use the ANSYS program to do numerical simulations that account for typical earth gravity is expressed in figure 6. This present article is useful for forecasting ω and comprehending stress distribution f_n, deformation patterns l_x, and general structural behavior $\alpha\tau$. Decisions about the railway track's design, maintenance, and safety in the face of ordinary earth gravity $n-1$ may be better understood with the help of this information. Railway track designs may be optimized and strengthened by including this gravity examine into ANSYS, which provides a realistic depiction of the track's behavior. When compared to existing method the proposed method enhances the standard earth gravity.

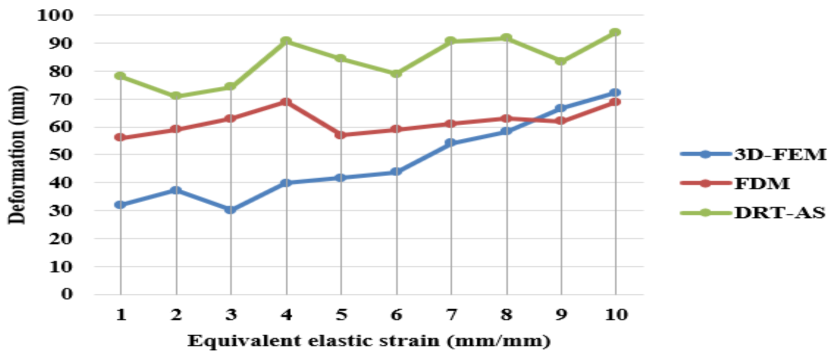

Figure 7: *Analysis of Equivalent Elastic Strain Distribution (mm/mm) with respect to deformation (mm).*

The equation (5), the equivalent elastic strain E_{es} is shown below:

$$E_{es} = \partial C_{max} = \frac{\gamma((a+1)-(b-1))}{2} \quad (5)$$

The ANSYS-based study of equivalent elastic strain in the deformation of the I-section is essential to comprehend the reaction of a railway track to applied loads ∂C_{max} is denoted in Figure 7. The track's behaviour under different loading situations γ may be understood by calculating the equivalent elastic strain, which is the deformation relative $(a+1)$ to the original material length $(b-1)$. Analyzing railway tracks in ANSYS involves measuring the amount of elastic deformation experienced by the track components using the equivalent elastic strain. Measured in millimeters per millimeter (mm/mm), this strain type indicates the proportion of the material's altered length to its initial length. By pinpointing possible stress hotspots and regions prone to greater strain, the equivalent elastic strain analysis findings aid in evaluating the track's structural robustness. To ensure the safety and durability of the railway track, as well as to make informed choices regarding design changes and maintenance regimens, this information is vital. Equivalent elastic strain is improved by the suggested strategy in comparison to the current one.

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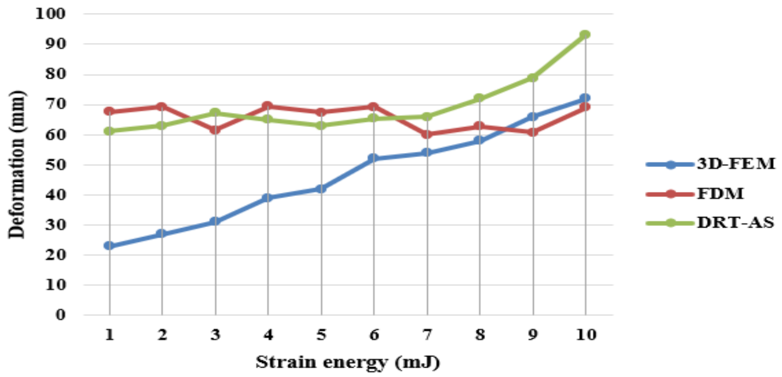

Figure 8: *Distribution of Strain Energy (mJ) with respect to deformation (mm).*

The equation (6), the equivalent elastic strain SE is shown below:

$$SE = (nh + v(x)\frac{rn}{(x+1)}.dn) \quad (6)$$

Figure 8 shows where ANSYS software reveals SE as part if I-section's deformation during application loads on railway tracks. For instance, strain energy gives valuable information regarding structural response for rail track sections such as those depicted above.Experimental results indicate an excellent agreement with numerical predictions from ANSYS program concerning material's deformation abilities under differing loading scenarios v(x). Millijoules per cubic meter(mJ), a unit used for measuring strain energy density meaning that it is defined as how much energy that can be stored per unit volume.Tying numerical simulations using ANSYS software into issues pertaining to rail-track I-profiles help locate places around rn where substantial amount s or low quantities h are absorbed. This study provides a full understanding of the material's response to applied loads (x+1) based on energy distribution. The strain energy analysis helps assess the track's structural performance by pinpointing regions with greater energy absorption dn or release. Decisions on design changes, material choices, and track safety depend on this data. Accordingly, the method suggested is better than the previous one in terms of Strain energy.

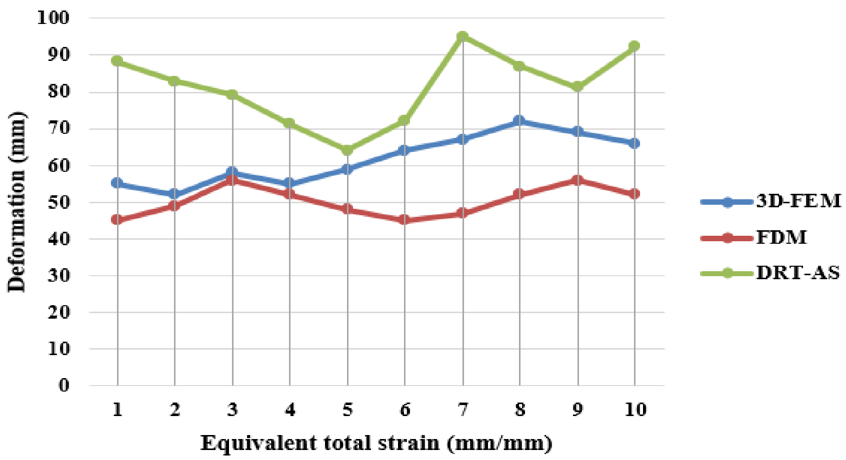

Figure 9: *Mapping of Equivalent Total Strain (mm/mm) with respect to deformation (mm).*

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The equation (7), the equivalent elastic strain $E_{total\ strain}$ is shown below:

$$E_{total\ strain} = (\vartheta r + w.(\frac{(de - pp)}{2(r+1)}.(hm * du) \quad (7)$$

To understand the total strain that occurs in a railway track when it is loaded, one must examine the total strain of the deformations of I-sections of the track as shown in Figure 9 using ANSYS software. The overall deformation can be measured by its equivalent total strain $\frac{(de-pp)}{2(r+1)}$, which includes elastic and plastic behavior of materials, measured in millimeters per millimeter (mm/mm), which is a dimensionless ratio w between its changed length hm and initial length du material. This type of strain is essential for a comprehensive examination of total deformation patterns ϑr and understanding the response of various portions of tracks to different types load conditions. Engineers can use the ANSYS program to perform digital simulation to determine how equivalent total strain w is distributed over various parts on the I-profile of a rail track. To visualize better and measure all deformations together with identification potential poorly performing areas 2(r+1) and stress concentration areas.The existence of high values indicates that some parts are experiencing high levels of equivalent total strains, therefore enabling structural integrity checks hm being done on them while making well informed decisions about design changes, maintenance strategies, safety and durability du concerns within the railway truck. When compared to previous methods used, this new approach improves Equivalent Total Strain considerably.

The ANSYS program together with a comprehensive numerical analysis has been used to provide insights on the behavior of I-section railway track deformation patterns. This makes it possible to improve track optimization and safety upgrades, which will help us understand normal earth gravity, elastic equivalent strain, strain energy, and total equivalent strains better. All this will eventually lead to enhanced design and maintenance of railway tracks for increased operational safety and reliability over time.

5. CONCLUSION:

This present research article reports methods for mitigating long-standing deformation of I-sections railway track using deformations in the railway track DRT-AS technique which is based on ANSYS software. The study uses modern numerical simulation tools like ANSYS software for conventional track designs as opposed to traditional ones done in the past. DRT-AS has enabled better detection of deformation zones, and it offers necessary design improvements by explaining different loading behaviors. This present article discusses important issues such as equivalent elastic strain, comparable total strain, normal earth gravity, etc. In a practical example, the proposed method has been implemented to assess stress distribution with respect to strain distribution and overall structural integrity. As concerns ordinary earth gravity; equivalent elastic strain; strain energy and equivalent total strain old techniques are surpassed by DRT-AS. Such results provide novel insights into connections between sub-surface structures or formation layers beneath tracks particularly those associated

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with underground geotechnical aspects resulting from different loadings coming from structures built on the ground surface above the ballast layer defined here in relation to soils below the ballast plane. Combined with ANSYS software, DRT-AS becomes a powerful tool for improving the safety and structural stability of railway tracks. Therefore, this current research enhances reliability in planning and operational safety of rail transport systems over an extended period thereby making it significant for design and maintenance of railways.

AUTHOR DECLARATIONS:

Conflict of Interest:

The authors have no conflicts to disclose.

DATA AVAILABILITY:

The corresponding author may provide the supporting data for the findings of this investigation upon reasonable request.

REFERENCE:

1. Wu, Y., Pun, C. L., Su, H., Huang, P., Welsby, D., Mutton, P., & Yan, W. (2022). Numerical study on ratcheting performance of heavy haul rail flash-butt welds in curved tracks. *Engineering Failure Analysis*, *140*, 106611.
2. Vignesh G, Barik D, Aravind S, Ragupathi P, Arun M. Numerical investigation of dimple-texturing on the turning performance of hardened AISI H-13 steel. International Journal for Simulation and Multidisciplinary Design Optimization. 2022;13:10..
3. Zou, L., Lu, L., Li, Y., Yang, K., Zhao, H., Dong, Y., & Zeng, D. (2023). Experimental and numerical study on press-fitted railway axles: Fretting fatigue behaviour in the very high cycle regime. *International Journal of Fatigue*, *166*, 107243.
4. Zhang, Z., Li, J., Wang, S., & Huang, X. (2022). A comparative numerical analysis of design variation plans for a shallow tunnel in very soft ground after a sudden accident. *Engineering Failure Analysis*, *141*, 106674.
5. Gardie, E., Dubale, H., Tefera, E., Bezzie, Y. M., & Amsalu, C. (2022). Numerical analysis of rail joint in a vertical applied load and determining the possible location of joints. *Forces in Mechanics*, *6*, 100064.
6. Vignesh G, Prakash M, Arun M. Numerical analysis on replacement of integrated planet carrier at maximum torque reduction stage in industrial gearbox. Materials Today: Proceedings. 2021 Jan 1;37:1729-33.
7. Gao, F., Zhao, T., Zhu, X., Zheng, L., Wang, W., & Zheng, X. (2023). Land subsidence characteristics and numerical analysis of the impact on major infrastructure in Ningbo, China. *Sustainability*, *15*(1), 543.
8. Fu, J., Zhao, N., Qu, Y., Yang, J., & Wang, S. (2022). Effects of twin tunnel undercrossing excavation on the operational high speed railway tunnel with ballastless track. *Tunnelling and Underground Space Technology*, *124*, 104470.

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

9. Jin, X. (2022). Research progress of high-speed wheel–rail relationship. *Lubricants*, *10*(10), 248.

10. Sun, Z., Zhang, D., Li, A., Lu, S., Tai, Q., & Chu, Z. (2022). Model test and numerical analysis for the face failure mechanism of large cross-section tunnels under different ground conditions. *Tunnelling and Underground Space Technology*, *130*, 104735.

11. Sayeed, M. A., & Shahin, M. A. (2023). Dynamic response analysis of ballasted railway track–ground system under train moving loads using 3D finite element numerical modelling. *Transportation Infrastructure Geotechnology*, *10*(4), 639-659.

12. Shi, C., Sun, X., Wang, T., Wu, Y., Liu, S., Wang, H., ... & Qie, L. (2022). Numerical analysis of dynamic behavior of Bi-block precast asphalt trackbed for High-Speed railway. *Construction and Building Materials*, *342*, 128088.

13. Wang, J., Han, J., Chen, J., Ding, G., Feng, G., Liu, T., & Guo, B. (2022). Experimental and numerical study on the dynamic response of a superthick backfill subgrade under high-speed railway loading: A case study of Qianjiang–Zhangjiajie–Changde railway. *Journal of Construction Engineering and Management*, *148*(12), 05022014.

14. Kwon, S. Y., & Yoo, M. (2022). Numerical Analysis Method for Liquefaction-induced Damage Evaluation to Railway Structure. *KSCE Journal of Civil Engineering*, *26*(9), 3752-3763.

15. Mandhaniya, P., Shahu, J. T., & Chandra, S. (2022, September). Numerical analysis on combinations of geosynthetically reinforced earth foundations for high-speed rail transportation. In *Structures* (Vol. 43, pp. 738-751). Elsevier.

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