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STEM-Based Analysis of the Semanggi Bridge Construction in Jember: A Contextual Physics Perspective

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ABSTRACT

This study aims to analyze the construction of the Semanggi Bridge in Jember using a Science, Technology, Engineering, and Mathematics (STEM) approach as an example of the application of physics and mathematics concepts in real-world infrastructure. The research employed a qualitative descriptive method using observation, documentation, and calculation analysis based on bridge geometric data obtained from digital maps and visual observations. The analysis focused on three vehicle paths representing inclined planes and circular paths to examine the concepts of uniformly accelerated motion, uniform circular motion, centripetal force, and the influence of friction on the maximum vehicle speed. In addition, technological and engineering aspects were analyzed, including the grade-separated interchange design, the use of prestressed concrete, pile foundations, and structural planning using civil engineering software. The results show that vehicle motion on the bridge can be explained through physics and mathematical concepts related to acceleration, slope angle, path radius, and friction. The study concludes that bridge construction can serve as a contextual learning medium for integrating STEM concepts in real-world applications

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INTRODUCTION

The Science, Technology, Engineering, and Mathematics (STEM) learning approach is a rapidly growing paradigm in education due to its ability to integrate diverse disciplines into a cohesive, contextual framework. This approach emphasizes the interconnectedness of scientific concepts, technological applications, engineering processes, and mathematical calculations, enabling students to transcend theoretical understanding and perceive real-world applications. Extensive research indicates that STEM-based learning enhances critical thinking, creativity, and problem-solving skills by engaging students in authentic analysis and design activities (Gusman et al., 2023; Khairunnisa & Tanjung, 2023; Lestari et al., 2024). Furthermore, the implementation of STEM through engineering projects has been proven to generate more meaningful learning experiences as students are directly involved in the design and testing phases (Ain et al., 2025; Sari & Hidayat, 2023). Consequently, the STEM approach is highly suitable for learning environments that utilize physical objects as primary learning resources.

In the digital era, the evolution of STEM learning has also expanded into interactive technologies. For instance, recent developments such as the AGILEST approach utilize machine learning agents and touchless Augmented Reality (AR) to facilitate kinesthetic learning or "learning by doing," providing personalized virtual instruction in subjects like Chemistry (Iqbal, 2023). While such digital innovations offer significant engagement, the use of tangible physical objects remains equally vital in helping students bridge the gap between abstract concepts and their daily surroundings. Contextual learning through physical artifacts has been shown to increase student involvement and simplify the comprehension of complex theories (Munawwaroh, 2024; Mawardi et al., 2024). One of the most relevant physical objects for STEM-based media is infrastructure construction, as it embodies an integrated application of science, technology, engineering, and mathematics. By analyzing construction, students can comprehend structural design, the mechanics of forces acting on a system, and the technology employed to ensure structural integrity and safety.

Bridges represent a prime example of engineering infrastructure suitable for STEM analysis. A bridge is a technical construction designed to support loads, maintain structural equilibrium, and ensure public safety. Its design process requires precise mathematical calculations, material selection, and engineering maneuvers to withstand various pressures during operation (Anggraini et al., 2021). Therefore, bridge analysis serves as an effective pedagogical tool to demonstrate real-world STEM implementation. Moreover, infrastructure-related learning helps students realize the critical importance of safety in public facilities.

The Semanggi Bridge in Jember is a specific structure that can be analyzed using the STEM approach. Its construction is meticulously designed to support traffic flow and safety. This bridge can be examined through various lenses: from scientific concepts such as Uniformly Accelerated Motion (GLBB), Newton's Laws, and circular motion, to construction technology, engineering design, and mathematical calculations regarding safe maximum driving speeds. Previous studies suggest that STEM analysis of the Semanggi Bridge serves as a contextual learning medium that enhances students' understanding of safety and structural mechanics (Baihaqi et al., 2025). Furthermore, integrating driving safety into the curriculum is crucial, as a lack of awareness contributes to high accident rates among adolescents (Rafi'ah et al., 2023). Educational activities that link safety to physical objects have been proven to raise student awareness regarding the responsible use of public facilities (Matyani et al., 2024).

Despite the widespread application of STEM, specific studies analyzing bridge construction—particularly the Semanggi Bridge in Jember—as a primary learning object remain limited. Utilizing real-world objects in STEM education provides a more profound learning experience and clarifies the relationship between science and daily life (Darmastuti et al., 2025; Syamsiandari et al., 2025). Thus, research analyzing the Semanggi Bridge construction through a STEM lens is essential to provide a comprehensive view of the synergy between science, technology, engineering, and mathematics. This study aims to analyze the construction of the Semanggi Bridge based on the STEM approach, with the expectation that the findings will serve as a reference for developing contextual learning that is more relevant to real-world challenges.

LITERATURE REVIEW

STEM education integrates science, technology, engineering, and mathematics to address real-world problems through interdisciplinary learning. The STEM approach encourages students to connect theoretical knowledge with practical applications and develop problem-solving skills relevant to modern scientific and technological challenges. According to Rodger W. Bybee (2013), STEM education emphasizes the integration of scientific inquiry, technological design, engineering practices, and mathematical reasoning in learning activities. Similarly, Todd R. Kelley and J. Geoffrey Knowles state that STEM learning allows students to understand how different disciplines interact in solving complex problems (Kelley & Knowles, 2016). Therefore, STEM-based learning is widely considered an effective approach to improve students' conceptual understanding and analytical thinking.

In physics education, contextual learning plays an important role in helping students understand abstract concepts through real-world phenomena. Contextual learning connects academic content with situations that students encounter in everyday life, enabling them to construct meaningful knowledge. Elaine B. Johnson explains that contextual teaching and learning helps students link theoretical concepts with practical experiences, making learning more relevant and engaging (Johnson, 2002). In this context, physical infrastructures such as roads, bridges, and transportation systems can be used as contextual examples to illustrate scientific principles in real situations.

Many physical phenomena related to transportation infrastructure can be explained using fundamental physics concepts. One important concept is circular motion, which occurs when a vehicle moves along a curved path. In such motion, a centripetal force is required to maintain the vehicle's trajectory toward the center of the curve. According to David Halliday, Robert Resnick, and Jearl Walker, the magnitude of centripetal force depends on the vehicle's speed, the mass of the object, and the radius of the circular path (Halliday et al., 2014). In road design, friction between the tires and the road surface also plays a crucial role in determining the maximum safe speed of a vehicle when passing through a curve.

Infrastructure such as bridges represents a practical application of integrated STEM concepts. Bridge construction requires scientific principles related to forces and motion, mathematical calculations for structural dimensions, technological tools for modeling and analysis, and engineering design to ensure structural safety and functionality. Modern bridge design also incorporates advanced materials and structural systems to improve durability and load-bearing capacity. Therefore, analyzing bridge structures can provide meaningful examples of how STEM principles are applied in real-world engineering projects.

Although many studies have discussed STEM-based learning and contextual physics education, limited research has explored the use of local infrastructure as a contextual STEM learning resource. In particular, the Semanggi Bridge in Jember has not been widely analyzed from a STEM perspective. Therefore, this study aims to analyze the construction of the Semanggi Bridge in Jember using the STEM approach in order to illustrate the application of physics and mathematical concepts in real-world infrastructure and to provide contextual examples that can support STEM-based learning.

METHODS

This study employs a descriptive qualitative research design with a Science, Technology, Engineering, and Mathematics (STEM) approach to analyze the integration of scientific concepts, technology, engineering, and mathematics within the construction of the Semanggi Bridge in Jember. A descriptive qualitative design was selected to systematically illustrate the phenomena occurring at the research site without manipulating the investigated variables. This qualitative approach allows for a profound understanding of the object through structured analysis based on field data and existing literature (Alam & Asmawi, 2024). The STEM framework is utilized to provide an integrated analysis of a real-world object, ensuring that every component of the bridge construction is evaluated through the dimensions of science, technology, engineering, and mathematics (Parameswari et al., 2023).

The research was conducted at the Semanggi Bridge in Jember, which served as the primary data source. Data were gathered through direct observation of the bridge structure, documentation in the form of photographs and construction diagrams, and relevant literature concerning STEM concepts and bridge engineering. The object was selected using purposive sampling, as the Semanggi Bridge possesses a unique structural design that can be comprehensively analyzed across all four STEM dimensions, making it an ideal candidate for contextual analysis. Utilizing tangible objects in STEM-based research facilitates a systematic explanation of the synergy between theoretical concepts and real-life applications (Siregar et al., 2025; Adeoye, 2023).

Data collection techniques included literature review, observation, and documentation. The literature review involved examining journals, books, and scientific sources related to STEM pedagogy, bridge construction, and qualitative methodology. Field observations focused on the structural components of the Semanggi Bridge, specifically regarding force distribution, load-bearing capacity, materials, and architectural design. Documentation was conducted by compiling photographs, blueprints, and supporting data regarding the bridge's form and function. These techniques are highly effective in qualitative research for obtaining factual data that reflect the actual field conditions (Rustamana et al., 2024; Rohmah & Aliah, 2023).

The research instrument consisted of a STEM analysis sheet containing indicators for science, technology, engineering, and mathematics. The science indicators encompass Uniformly Accelerated Motion (GLBB), Newton’s Laws of Motion, and circular motion within the bridge structure. Technology indicators cover the use of construction materials and modern building technologies. Engineering indicators focus on structural design and architectural planning. Mathematics indicators include the calculation of angles, forces, and maximum safe driving speeds. Data analysis followed the stages of data reduction, data display, and conclusion drawing/verification. The data obtained from observations and documentation were classified according to STEM aspects and subsequently analyzed to determine the interconnectedness of science, technology, engineering, and mathematics in the Semanggi Bridge construction. This systematic analysis ensures that the findings clearly illustrate the application of the STEM approach to real-world objects in a structured manner (Siregar et al., 2025).

RESULTS

Science Analysis

The scientific analysis was conducted by identifying the physical concepts used to evaluate the trajectory characteristics of the Semanggi Bridge pathway in Jember. Based on spatial observations utilizing Google Maps and Google Earth, the Semanggi pathway consists of three primary trajectories: an inclined plane trajectory, a circular trajectory, and an extended circular trajectory. Each trajectory was analyzed using mechanical concepts related to kinematics, dynamics, and driving safety. Figure 1 illustrates the Semanggi Jember pathway via Google Maps, while Figure 2 displays the Semanggi Jember pathway via Google Earth.

Figure 1. The Semanggi Jember Pathway as Viewed from Google Maps

Figure 2. The Semanggi Jember Pathway as Viewed from Google Earth

The first segment is an inclined plane trajectory, with an estimated length of approximately 30 meters based on scale measurements conducted via Google Maps. This segment represents the initial elevation change within the bridge's structural layout. Figure 3 illustrates the measured length of this first trajectory.

Figure 3. The Scale Measurement via Google Earth

In this trajectory, the concept of Uniformly Accelerated Motion (UAM)—or Gerak Lurus Berubah Beraturan (GLBB)—is applied to analyze the changes in vehicle velocity when traversing uphill or downhill sections. The key physical quantities considered in this segment include displacement, velocity, acceleration, and the road's inclination angle. The slope angle significantly affects the component of gravitational force acting parallel to the surface, which subsequently influences the vehicle's stability during motion. Furthermore, the analysis of the inclined plane segment incorporates gravitational force, normal force, and frictional force between the tires and the road surface, all of which are critical in maintaining vehicle stability.The second segment is a circular trajectory, analyzed using the principles of Uniform Circular Motion based on Newton’s Second Law. Based on observations from Google Earth satellite imagery, the curvature radius (r) of the Semanggi Jember turn is less than 30 meters; it is approximately half that distance, ranging between 10–15 meters. Consequently, for the purpose of this analysis, r is assumed to be 12.5 meters as an approximation. Figure 4 illustrates the measured radius of this second trajectory.

Figure 4. The Scale Measurement via Google Earth

In circular motion, a vehicle requires a centripetal force directed toward the center of the curvature to remain on its trajectory. For a vehicle navigating a curved road, this centripetal force is primarily provided by the frictional force between the tires and the road surface. If the friction is insufficient, the vehicle may undergo a lateral skid and deviate from the path. Consequently, road surface conditions—whether dry or wet—significantly influence vehicle safety when traversing circular segments. Conceptually, centripetal force is a net force acting toward the center of rotation and can originate from friction, tension, or gravitational components. The magnitude of the centripetal force is determined by the object's mass, velocity, and the radius of the trajectory. The equation for centripetal force is expressed as follows:

$$F_s = \frac{m\,v^2}{r}\text{..........................}(1)$$

In circular motion, a vehicle also exhibits a tendency to move away from the center of curvature due to inertia, a phenomenon often referred to as the pseudo-centrifugal force. To ensure the vehicle remains on its intended path, the frictional force must be capable of providing the necessary centripetal force, thereby preventing the vehicle from sliding out of the circular trajectory. The equation for centrifugal force is expressed as follows:

$$F_g = \mu\,N\text{...........................}\ (2)$$

The third segment possesses a geometric configuration identical to the second segment, characterized as a circular trajectory with an estimated radius of the same magnitude based on satellite imagery observations. Consequently, the physical principles applied to this third segment remain consistent with the second, utilizing uniform circular motion where the centripetal force is derived from the friction between the tires and the road surface. Due to this structural symmetry, the kinematic characteristics of vehicles on both the second and third segments follow identical physical principles; thus, the driving safety analysis for both trajectories employs the same conceptual framework. The results of the scientific analysis indicate that vehicle safety on the Semanggi pathway is significantly influenced by the trajectory's geometry, the road's inclination angle, the radius of curvature, and the magnitude of the frictional force, which collectively determine the vehicle's ability to maintain its path.

Mathematic Analysis

The mathematical analysis was conducted to determine the physical quantities associated with trajectory length, acceleration, inclination angles, forces, and the maximum vehicle speed on the Semanggi Jember Bridge pathway. Calculations were performed based on spatial measurements obtained from Google Maps and Google Earth, alongside assumed vehicle speed values utilized for the driving safety analysis.

In the first trajectory, which is an inclined plane, the segment length was derived from scale measurements on Google Maps, totaling approximately 30 meters. The displacement was subsequently calculated using Equation (3).

$$\Delta x = x_t - x_0 = 297\ m - 0\ m = 297\ m \text{ to the left side} \text{ .... } (3)$$

The vehicle's acceleration is determined using the linear motion with constant acceleration equation, as shown in Equation (4).

$$a = \frac{v_t - v_0}{\Delta t} \text{ .... } (4)$$

The vehicle's initial and final speeds are assumed to be 20 km/h and 50 km/h, respectively. These values are converted to m/s to calculate the vehicle's acceleration.

$$a = \frac{v_t - v_0}{\Delta t} = \frac{13{,}89 - 5{,}56}{44{,}4} = 0{,}187\ m/s^2$$

The slope angle of the track is determined by the ratio of its height to its length; thus, the angle is derived from the trigonometric relationship expressed in Equation (5).

$$sin\,\theta = \frac{h}{s} \text{ .... } (5)$$

$$\sin\theta = \frac{98}{297} = 0{,}3299$$
$$\theta = sin^{-1} 0{,}3299$$
$$\theta = 19{,}27°$$

Based on the calculated slope angle, the gravitational force, normal force, and frictional force acting on the vehicle are determined using the following equations:

$$W = mg = 149\ x\ 9{,}8 = 1460{,}2\ N \text{ .... } (6)$$

$$N = W\,cos\,\theta = 1460{,}2\ N\ x\ cos\ 19{,}27° = 1378{,}4\ N \text{ .... } (7)$$

$$\sum F_x = ma \text{ .... } (8)$$
$$W\ \sin\theta - f_k = m_{total}a$$

$$f_k = W \sin\theta - m_{total}\, a$$
$$f_k = 1460{,}2\ N\ \times \sin 19{,}27° - (149\ kg\ \times 0{,}187 \frac{m}{s^2})$$
$$f_k = 481{,}89 - 27{,}863 = 454{,}027\ N$$

The coefficient of friction is determined by the ratio of the frictional force to the normal force, providing a value used to analyze driving safety on inclined tracks.

$$f_k = \mu_k N \ \ldots\ldots\ldots\ldots.(9)$$
$$\mu_k = \frac{f_k}{N}$$
$$\mu_k = \frac{454{,}027\ N}{1378{,}4\ N} = 0{,}329$$

For the second track, which is circular in shape, the maximum vehicle speed is calculated using the circular motion equation as shown in Equation (10).

$$v_{max} = \sqrt{\mu_s\ g\, r}\ \ldots\ldots\ldots\ldots\ldots.\ (10)$$

where *r* represents the radius of the track and μ denotes the coefficient of friction between the tires and the road surface. The calculations are performed across various road conditions with different friction coefficients, namely dry, wet, and very wet surfaces. The gravitational acceleration is set at 9.8 m/s^2. The results indicate that the maximum vehicle speed varies depending on the road surface condition. Under hot weather and dry road conditions (\mu =), the maximum speed is obtained as follows:

$$v_{max} = \sqrt{0{,}8\ x\ 9{,}8\ x\ 12{,}5} = 9{,}89 \frac{m}{s} = 35{,}64\ \frac{km}{jam}$$

Furthermore, under rainy weather and wet road conditions ($\mu_s = 0{,}3$), the maximum speed is obtained as follows:

$$v_{max} = \sqrt{0{,}3\ x\ 9{,}8\ x\ 12{,}5} = 6{,}06 \frac{m}{s} = 21{,}82\ \frac{km}{jam}$$

Under extremely wet or slippery road conditions (extreme conditions), the static friction coefficient between the vehicle tires and the road surface is assumed to be approximately $\mu_s = 0{,}1$. This value is used to represent the worst-case safety scenario.

$$v_{max} = \sqrt{0{,}3\ x\ 9{,}8\ x\ 12{,}5} = 6{,}06 \frac{m}{s} = 12{,}6\ \frac{km}{jam}$$

The third track has the same geometry as the second track; therefore, the radii of both tracks are considered identical. Consequently, the maximum speed calculation for the third track utilizes the same equation as the second, yielding the same results. The maximum speed is independent of the vehicle's mass, as it is solely influenced by the track radius, gravitational acceleration, and the coefficient of friction between the tires and the road surface. The calculated maximum speeds for the circular tracks are summarized in Table 1.

Table 1. Calculation Results of Maximum Vehicle Speed on Circular Tracks

Road Condition	Friction Force	Radius (m)	Maximum speed (m/s)	Maximum speed (km/h)
Dry	0,8	12.5	9,89	35,64
Wet	0,3	12.5	6,06	21,82
Very Wet	0,1	12.5	3,5	12,60

Based on the calculation results, the maximum vehicle speed on circular paths is influenced by the friction coefficient between the tires and the road surface, as well as the track's radius of curvature. The obtained maximum speeds range from 12 km/h to 36 km/h, depending on the road surface conditions.

Engineering Analysis

The engineering analysis evaluates the structural planning, geometric design, and traffic engineering of the Semanggi Bridge construction in Jember. Based on the analysis, this bridge is designed as a grade-separated intersection utilizing a trumpet interchange configuration. This design allows vehicles to change directions without stopping at intersections, thereby reducing congestion and enhancing road user safety. Geometric planning considers traffic flow direction, vehicle volume, and potential conflict points at the intersection. Consequently, curved ramps with specific radii are implemented to ensure safe vehicle maneuvers. The geometric design also accounts for road cross-slopes, curve radii, and lane widths to comply with road safety standards. Figure 5 illustrates the bridge type.

Figure 5. The Trumpet Interchange Configuration of the Semanggi Bridge in Jember

From a structural perspective, the planning accounts for vehicle loads, wind loads, and potential seismic loads. Key components such as piers, girders, and floor slabs are designed to withstand compressive forces, tensile forces, and bending moments. Pile foundations are utilized to ensure that bridge loads are transferred to soil layers with higher bearing capacity, maintaining structural stability. Reinforced concrete piers (columns) function to support vertical loads from the girders and transfer them to the foundation. Steel or prestressed concrete girders are employed due to their ability to support heavy loads over longer spans with fewer supports while bracing the bridge deck.

For shorter spans, conventional reinforced concrete girders are used. The bridge deck or floor slab consists of reinforced concrete for vehicle traffic. Finally, railings made of light-gauge steel or concrete serve as lateral protection. Figure 6 illustrates the bridge structure, while Figure 7 shows a typical cross-section of the bridge.

Figure 6. Structural Components of the Semanggi Bridge, Jember.

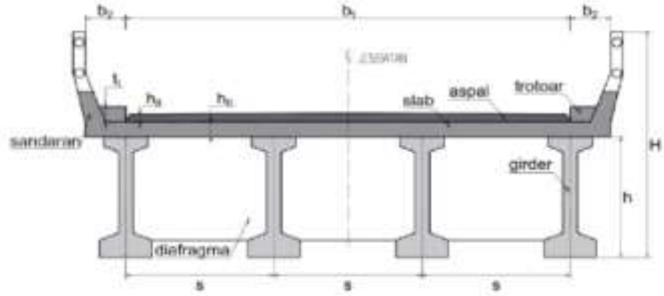

Figure 7. Typical Cross-Section of the Bridge.

In the engineering process, bridge construction also involves project management planning and occupational safety. The construction process is carried out through coordination between planners, contractors, and field supervisors. The implementation of workplace safety procedures is essential to mitigate the risk of accidents during construction. Furthermore, the use of a grade-separated intersection design is the result of engineering calculations aimed at improving traffic flow and reducing the likelihood of accidents at the intersection.

Technology Analysis

The technology aspect analysis identifies the construction technology and engineering systems utilized in the development of the Semanggi Bridge in Jember. Based on observations, this bridge employs a grade-separated intersection design featuring flyovers and curved ramps to manage vehicle movements from various directions, as shown in Figure 8. In this design, traffic lights are not utilized at the main intersection points because vehicle flows are separated by different elevations. Vertical lane separation ensures that vehicle paths do not intersect on the same plane, thereby significantly reducing traffic conflicts.

Figure 8. Modern Grade-Separated Design of the Semanggi Bridge in Jember.

The main bridge structure utilizes prestressed concrete technology. Prestressed concrete possesses high compressive strength, enabling it to support heavy vehicle loads and allowing for longer bridge spans. Furthermore, the use of prestressed concrete enhances the structure's resistance to dynamic loads caused by vehicle movement. For the foundation, reinforced concrete piles are used to transfer the structural loads to more stable soil layers. The application of piles is commonly implemented in areas with unstable soil conditions to ensure the bridge remains secure and does not experience excessive settlement. Figure 9 illustrates the application of prestressed technology and pile foundations.

Figure 9. Application of Prestressed Technology and Pile Foundations

During the construction process, engineers employ modular or prefabrication methods for several structural components, such as the bridge girders. These components are manufactured in a factory and then assembled at the project site. This method accelerates the construction timeline and ensures high component quality through better-controlled production environments. Furthermore, structural planning is conducted using civil engineering analysis software, such as SAP2000, MATLAB, or MIDAS Civil. These tools are used to calculate forces, bending moments, and shear forces across all structural elements, ensuring the design complies with rigorous safety standards.

DISCUSSION

The results of this study indicate that the construction of the Semanggi Bridge in Jember can be analyzed using a Science, Technology, Engineering, and Mathematics (STEM) approach, allowing physics and mathematical concepts to be explained through real-world objects. In the science analysis, the motion of vehicles on inclined and curved paths can be described using the concepts of uniformly accelerated linear motion and uniform circular motion. These findings are consistent with previous studies which state that phenomena in road and bridge construction can be used to explain concepts of force, acceleration, and centripetal force in contextual physics learning. The use of real-world examples enables abstract concepts to become easier to understand because students can directly observe their applications in everyday life.

In the mathematics analysis, the calculation of the maximum vehicle speed shows that the velocity is strongly influenced by the radius of the path and the coefficient of friction between the tires and the road surface. This result is consistent with the theory of circular motion dynamics, which states that centripetal force must be fulfilled for a vehicle to move stably along a curved path. These findings support previous research indicating that mathematical approaches in road structure design are necessary to ensure road user safety, particularly on curves with small radii. Thus, mathematical analysis is not only theoretical but also plays an important role in infrastructure design.

The results in the technology aspect show that the Semanggi Bridge utilizes a grade-separated interchange design, prestressed concrete, and pile foundations to enhance structural strength and stability. The use of these technologies is consistent with modern engineering practices aimed at reducing traffic conflicts and improving road user safety. In addition, the application of modular construction methods and structural modeling using civil engineering software demonstrates that bridge construction involves complex planning technologies. This finding supports previous research stating that the integration of technology in modern construction is essential to produce structures that are safe, efficient, and capable of withstanding dynamic loads.

In the engineering analysis, the bridge design reflects considerations of road geometry planning, material selection, and traffic flow management that prioritize user safety and comfort. Structural engineering in grade-separated intersections allows vehicles to move without crossing at the same level, thereby reducing the risk of accidents. These results indicate that the engineering aspect is not only related to structural strength but also to the planning of safe and efficient transportation systems.

This study has several strengths, including the use of a real-world object as the source of analysis, allowing STEM concepts to be explained in a contextual and easily understandable manner. Furthermore, the analysis integrates the four STEM aspects comprehensively, providing a more complete overview of the application of science and mathematics concepts in infrastructure engineering. However, this study also has limitations, as measurements were based on estimations from digital maps and visual observations, meaning that the calculations did not use official technical data from the construction planners. Therefore, the obtained values represent an approximation intended for learning analysis purposes.

The implication of this study is that bridge construction can be used as a contextual learning medium to integrate science, technology, engineering, and mathematics concepts. The use of real-world objects in learning can help improve conceptual understanding and demonstrate the relationship between theory and its application in everyday life. Future research is recommended to use more complete technical data and conduct analyses on other structures in order to obtain more accurate results and support the development of STEM-based learning.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that the construction of the Semanggi Bridge in Jember reflects the integration of multidisciplinary concepts within the Science, Technology, Engineering, and Mathematics (STEM) framework. From the science perspective, vehicle motion on the bridge can be explained through the concepts of uniformly accelerated motion on an inclined plane and uniform circular motion on curved paths. From the mathematics perspective, the maximum vehicle speed is influenced by the radius of the path, gravitational acceleration, and the coefficient of friction, which determine the centripetal force required to maintain vehicle stability on curves.

From the technology aspect, the bridge utilizes a grade-separated interchange design, prestressed concrete structures, and pile foundations to ensure structural strength and stability. Meanwhile, the engineering analysis highlights the importance of structural safety, road geometry planning, and traffic flow management in reducing vehicle conflicts and improving traffic efficiency. Overall, the Semanggi Bridge in Jember can serve as a contextual example for integrating STEM concepts, enabling theoretical knowledge to be understood through real-world infrastructure.

FURTHER STUDY

This study has several limitations; therefore, further research on the integration of STEM concepts in the Semanggi Bridge in Jember is needed to enrich the findings and provide deeper insights for readers and researchers. Future studies are recommended to develop instructional materials, such as handouts or learning modules, based on the STEM analysis presented in this study. These materials can then be validated by experts and implemented in classroom learning to evaluate their effectiveness in improving students' conceptual understanding. Such investigations would strengthen the practical application of this research in STEM-based physics learning.

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