Design and Simulation of Fiber Optic Cable using SolidWorks for Landslide Monitoring

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Abstract. This paper presents fiber optic cable design and simulation using SolidWorks software. SolidWorks software is an effective tool that helps design, analyze, and give a better understanding of fiber optic cable capabilities and performances. The model of the fiber optic cable was developed based on the existing fiber optic drop cable. It is composed of mainly four parts: Fiber optic member, fiber-reinforced plastic (FRP) strength member, low smoke zero halogen (LSZH) jacket, and steel wire. A static study was performed to determine the designed model's ability to endure various levels of pressing and pulling forces. Simulation results showed that the cable can withstand a maximum of 195 N pulling force and 30000 N pressing force with a displacement of 1.78e+02 mm and 4.94e-01 mm respectively. The findings will contribute to the design of a new or novel fiber optic cable that is capable to monitor landslide activities with higher durability in future studies.

1. Introduction
Landslides occur when natural stability is disrupted, resulting in soil and rock movement down the slope. A devastating landslide results in a high rate of death and significant environmental damage. To minimize losses and prevent damages, it is vital to monitor and predict landslides. Many strategies for monitoring landslides have been discussed during the last few decades [1–8]. The methods are useful for comprehending slope displacement. On the other hand, real-time monitoring can only provide an effective landslide monitoring system for early detection to reduce the risk factors by understanding the dynamic behavior of landslides. Fiber optics exhibiting various applications has been adopted in landslide monitoring and it is successful. Many researchers reportedly used fiber optics to detect early signs of slope displacement. Moreover, experiments on slope deformation at landslide-prone zones based on optical fiber have been done [3, 9–16].

Despite fiber optic is not new for landslide monitoring, the development and integration of new concepts in it would compete favorably with the existing monitoring concept and expand the possibilities and perspectives. Since fiber optic is relatively small, it has better reliability, faster transmission, higher flexibility, longer sensing distance, and immune to electromagnetic interference, it is the best choice for landslide monitoring in the future [17–23]. There are many types of fiber optic cable such as drop cable,
indoor cable, outdoor cable, and armored cable [23]. Fiber optic cable with improved specifications, structure and materials would strengthen the cable and also contribute to better sensing and load withstand capability. To the best of the authors’ knowledge, there are no studies investigate the load withstand capability of a fiber optic cable.

In this paper, a 3D model of a drop cable is designed using SolidWorks software. The 3D model is drawn with detailed specifications and material properties to study the cable strength, capability and performance by analyzing the strain, stress, and displacement of the fiber optic cable under the static analysis process. Designing using SolidWorks saves time and allows for many tests to be run on the model to check the fiber optic cable performance. The findings from this paper can provide a better understanding of a fiber optic cable in load withstand capability. Also, the findings would contribute to the design of a new or novel fiber optic cable for implementing effective landslide monitoring in future studies.

2. **Methodology**

The methodology for this research comprises a design process of sketching a 3D model of fiber optic cable using appropriate materials and evaluate the model. Fiber optic cable is designed using SolidWorks software and the design specification is based on the current market available fiber optic cable i.e. self-supporting bow-type drop cable with the fiber optic member in the center, two parallel fiber-reinforced plastic (FRP) members are placed at the two sides, with a steel wire acting as the additional strength member and then the cable is covered with low smoke zero halogen (LSZH) material jacket [24]. The SOLIDWORKS® application is mechanical design automation software. It is a simple tool to design, experiment, and analyze [25]. A comprehensive structural analysis solution is fully embedded within SOLIDWORKS making it a powerful tool to be used by designers and analysts. Figure 1 depicts the basic stages involved in creating a design model. The design process has three main stages: Part Module, Assembly Module, and Drawing Module.
2.1. **Part Module**

The flowchart of the design process to create a Part Module is shown in Figure 2. First, the Part Module of fiber optic is designed by sketching the 2D model with the respective dimensions of the fiber. Second, the part is extruded to create a solid 3D feature where the 2D sketch to 3D model takes place. Then, the material is added to the part correspondingly. Finally, the Part Module for the design process is done. This process is repeated for each part of the design. In the design, there are five parts: fiber core and cladding, FRP member, steel wire, and LSZH jacket. This part module is saved for the assembly module process.

2.2. **Assembly Module**

The flowchart of the design process to create an Assembly Module is shown in Figure 3. Assembly is the combination of Parts or Sub-Assemblies. Firstly, the Assembly Module of fiber optic is created by inserting components or multiple parts. In this design, there are six components: fiber core and cladding, two FRP members, steel wire, and LSZH jacket. These multiple components are put together to form an assembly. Then, the mating is done by moving and rotating the components in the preferred direction to create a geometric relationship using mates, concentric and coincident. Lastly, the dimensions of the 3D assembled model are checked and saved. Any changes to the part module reflect on the corresponding assembly module and vice versa.
2.3. Drawing Module

Drawings are created from part or assembly models. This feature can be selected from the tools and can select the drawing template or drawing sheet. Drawings can be viewed in multiple views such as isometric views (3D) and standard views. The dimensions for the drawing can be derived from the model document and using add annotations.

The development of the structural design of the fiber optic cable is shown in Figures 4 and 5. The basic model sketch of the design, the top view, and the isometric view is shown in Figure 4 (a) and (b). The designed structure of the fiber optic cable and model exhibiting the respective parts of the design: fiber optic member (core and cladding), LSZH jacket, FRP, and steel wire are shown in Figure 5. The center of the cable is the fiber optic member comprising of core and cladding. Either side of the fiber optic member has an FRP. Also, there is a supporting steel wire on one side and LSZH is used as the cable jacket.

![Figure 4. Model Sketch - (a) Top view and (b) Isometric view](image-url)
Figure 5. Design Model
Figure 6 illustrates the top view of the structural design and dimensions of the fiber optic cable. The center of the cable is the fiber optic member with core and cladding with the diameter of $d_1$ and $d_2$, respectively. Either side of the fiber optic member has an FRP strength member with a diameter of $d_3$. There is a supporting steel wire on the side with inner and outer diameters of $d_4$ and $d_5$, respectively. Finally, all these are covered by an LSZH jacket. And the total length of the fiber model by boss extrude is 500 mm.

![Figure 6. Fiber Optic Cable Specification](image)

To analyze the stress, strain, and displacement of the fiber optic cable, the material properties for each part of the cable must be defined in SolidWorks. The material properties can be accessed from the material database or be defined as a custom material. Table 1 below shows the material properties for different parts of the designed fiber optic cable.

|                          | Fiber Optic Member | FRP Strength Member | LSZH Jacket | Steel Wire |
|--------------------------|--------------------|---------------------|-------------|------------|
| **Yield strength N/m$^2$:** | 7e+08              | 8.11e+08            | 1.8e+7      | 2.06843e+8 |
| **Tensile strength N/m$^2$:** | 5e+09              | 1.622e+09           | 2.49e+7     | 1.57e+09   |
| **Elastic modulus N/m$^2$:** | 7.245e+10          | 5.302e+10           | 4e+8        | 2e+11      |
| **Poisson's ratio:**     | 0.17               | 0.35                | 0.35        | 0.29       |
| **Mass density kg/m$^3$:** | 2.440              | 2630                | 940         | 7.870      |
The simulation test of the designed fiber optic cable is done using the Motion Study. The simulation flowchart is shown in Figure 7. The first step is to create a New Study and select Static analysis. The static study is used to study the stress, displacement, and strain of the design parts. Next, applying fixture and external force to the respective design’s part followed by mesh and run process.

![Simulation Flowchart](image)

**Figure 7. Simulation Flowchart**

In this study, two types of external forces (pulling force and pressing force) were applied to the fiber optic cable for static studies. For pulling force: the bottom face of the fiber optic cable is fixed using the fixture (green arrow) and pulling force is applied to only the top face by creating a force-directed outwards (purple arrow) as shown in Figure 8. For pressing force: new split line of 50 mm is created in the front face at the center of the fiber optic cable, the back face of the fiber optic cable is fixed using the fixture (green arrow), and pressing force is applied to only the front face on the split area of 50 mm (purple arrow) as shown in Figure 9. After the successful mesh and running of the study, simulation is said to be completed, and the results can be extracted in word or pdf form.
Figure 8. (a) Fixed bottom face and (b) pulling force at the top face

Figure 9. (a) Fixed only the back face and (b) pressing force at a particular slit of the front face
3. **Results and Discussion**

Static studies on the fiber optic cable were carried out based on the different pulling and pressing forces that were applied to the fiber optic cable model. Fiber optic is the most important component inside a fiber optic cable because it is responsible for signal transmission. The deformation of the fiber optic in the cable would drastically affect the reliability and performance of the landslide monitoring system using the fiber optic cable.

Table 2 shows the result of static analysis for applying different pulling force values on the fiber optic cable. The pulling force values ranging from 5 N to 200 N are applied to determine the maximum pulling force that would cause the permanent deformation of the fiber optic. From Table 2, a pulling force of 195 N would produce maximum stress of 6.98e+08 N/m\(^2\) which is just below the yield strength of the fiber optic member (7e+08 N/m\(^2\)) as shown in Table 1. This can be concluded that the maximum pulling force that the cable can withstand before permanent deformation of the fiber optic cable is estimated to be at 195 N. At the pulling force of 195 N, the maximum displacement and strain are at 1.78e+02 mm and 7.13e-02 respectively. As for the pulling force of 196 N, the maximum stress exceeds the fiber optics yield strength and this causes the permanent deformation of the fiber optic.

**Table 2.** Static analysis results for different pulling forces.

| Pulling Force (N) | Stress (min) N/m\(^2\) | Stress (max) N/m\(^2\) | Displacement (max) mm | Strain (min) | Strain (max) |
|-------------------|------------------------|------------------------|-----------------------|--------------|--------------|
| 5                 | 3.64e+01               | 1.79e+07               | 4.56e+00              | 5.55e-08     | 1.66e-03     |
| 10                | 1.05e+02               | 3.58e+07               | 9.12e+00              | 1.28e-07     | 3.42e-03     |
| 50                | 6.13e+02               | 1.79e+08               | 4.56e+01              | 5.98e-07     | 1.75e-02     |
| 100               | 6.98e+02               | 3.58e+08               | 9.12e+01              | 1.26e-06     | 3.49e-02     |
| 150               | 1.38e+03               | 5.36e+08               | 1.37e+02              | 1.96e-06     | 5.19e-02     |
| 180               | 1.81e+03               | 6.44e+08               | 1.64e+02              | 1.88e-06     | 6.20e-02     |
| 190               | 1.46e+03               | 6.81e+08               | 1.73e+02              | 2.33e-06     | 6.64e-02     |
| 195               | 2.13e+03               | 6.98e+08               | 1.78e+02              | 2.33e-06     | 7.13e-02     |
| 196               | 1.90e+03               | 7.03e+08               | 1.79e+02              | 2.21e-06     | 6.63e-02     |
| 200               | 1.75e+03               | 7.18e+08               | 1.82e+02              | 2.48e-06     | 7.01e-02     |

Table 3 shows the result of static analysis for applying different pressing force values on the fiber optic cable. The pressing force values from 5 N to 32000 N are applied to determine the maximum pressing force that would cause the permanent deformation of the fiber optic. From Table 3, a pressing force of 30000 N would produce maximum stress of 6.67e+08 N/m\(^2\) which is just below the yield strength of the fiber optic member (7e+08 N/m\(^2\)) as shown in Table 1. This can be concluded that the maximum pressing force that could be withstood by the cable is about 30000 N before the fiber optic permanent deformation occurs. At the pressing force of 30000 N, the maximum displacement and strain are at 4.94e-01 mm and 3.33e-01 respectively. As for the pressing force of 31000 N, the maximum stress is greater than the yield strength of the fiber optic and this will cause the permanent deformation of the fiber optic.
### Table 3. Static analysis results for different pressing forces.

| Pressing Force N | Stress (min) N/m^2 | Stress (max) N/m^2 | Displacement (max) mm | Strain (min) | Strain (max) |
|------------------|--------------------|--------------------|-----------------------|--------------|--------------|
| 5                | 1.01e-12           | 1.11e+05           | 8.24e-05              | 2.77e-17     | 6.56e-05     |
| 10               | 9.34e-13           | 2.27e+05           | 1.65e-04              | 6.41e-17     | 1.31e-04     |
| 50               | 3.00e-12           | 3.10e+06           | 8.23e-04              | 2.32e-16     | 6.56e-04     |
| 150              | 9.39e-13           | 3.28e+06           | 2.48e-03              | 1.58e-15     | 1.97e-03     |
| 2000             | 2.52e-10           | 4.41e+07           | 3.30e-02              | 1.07e-14     | 2.63e-02     |
| 4500             | 2.16e-07           | 1.01e+08           | 7.43e-02              | 5.76e-14     | 5.90e-02     |
| 5000             | 1.15e-09           | 1.12e+08           | 8.26e-02              | 2.40e-14     | 6.56e-02     |
| 15,000           | 9.02e-11           | 3.33e+08           | 2.48e-01              | 1.15e-13     | 1.68e-01     |
| 25000            | 1.45e-10           | 5.60e+08           | 4.12e-01              | 1.33e-13     | 2.80e-01     |
| 30000            | 1.01e-10           | 6.67e+08           | 4.94e-01              | 1.72e-13     | 3.33e-01     |
| 31000            | 2.08E-10           | 7.01E+08           | 5.12E-01              | 3.03E-13     | 3.46E-01     |
| 32000            | 1.93E-10           | 7.24E+08           | 5.27E-01              | 1.79E-13     | 3.55E-01     |

As a result of the static analysis simulation, distribution of von Mises stresses, displacements, and strains were obtained for the 195 N pulling force and 30000 N pressing force as shown in Figures 10 and 11 respectively. From the figure, it is clear that the maximum stress is less than the yield strength of fiber optic at the particular pulling and pressing forces. The fiber optic cable could endure a higher pressing force in comparison with the pulling force. This is due to the pressing force is applied on higher fiber optic cable’s surface area as compared with pulling force. Also, the maximum displacement for pressing force of 30000 N is only 4.94e-01 mm as compared with the pulling force of 195 N which exhibits a maximum displacement of 1.78e+02 mm. As the fiber optic cable is buried under the ground for landslide monitoring, the high pressing force withstanding capability of the designed cable will further support the implementation of the cable in landslide monitoring.
Figure 10. The result of static analysis for fiber optic cable at Pulling Force = 195 N.
Figure 11. The result of static analysis for fiber optic cable at Pressing Force = 30000 N.
4. Conclusion
In this paper, a 3D model of the fiber optic cable was built successfully using SolidWorks. From the first stage of building the parts, then assembling the different parts to form an assembly, and finally developing the 3D model of fiber optic cable. This paper gives clear steps to design a fiber optic cable carefully with specified dimensions and material properties. A static analysis study is used to determine the maximum pulling and pressing force that can be withstood by fiber optic cable. Results showed that the cable can withstand a maximum of 195 N pulling force and 30000 N pressing force with a displacement of 1.78e+02 mm and 4.94e-01 mm respectively. A laboratory test will be conducted to verify the simulation results in this study. These findings contribute to the design of a new or novel fiber optic cable for implementing an effective landslide monitoring system in future studies.

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