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Physical Characterization of Fibre Optic Cable using Simple Laboratory Stress Tests

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Abstract

Most learning institutions in Zimbabwe use fibre optic cable for internet connectivity and the heavy human and vehicular traffic at these places may pose a threat to maintenance of the cable particularly on semi-rigid ground. Physical stress in form of pressure exerted on the cable by the said traffic need to be investigated and compared in relation to tensile strength of the cable. The cables are made of polymers which provide a good operating temperature, chemical resistance, bio compatibility and prevention to mechanical and chemical damage. Simple Physics lab tests offer an opportunity to investigate the stress and strain parameters of the cable. The study sought to determine the Young modulus of the fibre optic cable at Great Zimbabwe University using two methods namely : the centre span deflection method and the strain gauge method. The first method was based on adding standard weights to cable tied on horizontally on two ends and observing deflections from the equilibrium position, the second method involved adding standard weights to a vertically suspended fibre optic and observing extensions from original length. Results of the two methods were processed in linear equations which estimated a Young modulus constant for the cable which is a stress parameter that indicated the strength of the cable. The values for Young modulus for center span deflection method using three specimens of different lengths were 8.67×10^{10} N/m^2, 2.34×10^{11} N/m^2 and 1.78×10^{11} N/m^2 with 0.003% error. For the strain gauge method readings obtained from two specimens of different lengths were 6.48×10^6 N/m^2, 9.47×10^6 N/m^2 with 0.3% error. Method 1 however gave values that are close to the literature figures and can be relied on to provide stress indicator values.

Keywords: Maintenance; Stress; Fibre optics; Load; Young modulus

Introduction

There has been remarkable growth in the last decade in the use of Information and Communication Technology (ICT) in Zimbabwe. This has been as a result of the government effort to be at par with the rest of the world. A long period had been spent in the use copper cables and satellite communication and this hindered a lot of business opportunities to the country [1]. Zimbabwe now uses both fibre optics and copper cables, powerline communication and wireless systems. Through such companies TelOne, Powertel Zimbabwe, Liquid telecom and Telco, the country has been able to harness internet services through undersea highway using fibre optics linked through Mozambique and South Africa. Ndlovu [2] in the ICT guide stated the following benefits of using fibre optics in Zimbabwe; greater social interaction, creation of employment, improved business efficiencies, widening people's freedom, as well as access to information and knowledge. There has been establishment of a fibre optic network linking main cities and towns in Zimbabwe. This is in a bid to harmonise infrastructure and create a national communication system that reaches all corners of the country [3].

Masvingo, Zimbabwe's third largest city has had the pleasure of enjoying this benefit of networking using fibre optic as it benefited from the 2011, US$15 million national budget that was allocated for the Harare-Bulawayo and Harare-Masvingo fibre optic project [4]. The city has many industries, buildings colleges as well as good tourist sites. It also has the only state owned university, Great Zimbabwe which has an annual enrolment of 16000 students per year. This large influx of students results in huge volumes of traffic surfing the net hence the adoption of faster modes of data transfer are required which can only be achieved through the use of fibre optics. In order to achieve this, the university has more 5000 m of fibre optic cable buried underground around the campuses.

The high volumes of students and vehicles driven pose a maintenance problem to the fibre cable due to pressure that can be exerted from above the ground, especially non-rigid ground. Rigid ground like concrete slab exert an opposite and equal upward force to the downward force from the object resting above the ground according to Newton's 3rd law of motion and pose no threat to the cable as the forces cancel out. Most fibre optics cables are made from polymers of transparent to light, flexibility e.g. Poly methyl acrylate (PMMA) which is used as core materials. Micro cables are designed for jetting using high density polyethylene (HDPE) outer sheaths to reduce friction of micro ducts. The polymers provide stiffness that help in preventing bucking and make it easy for the fibre to negotiate changes in the micro duct [5]. The polymers provide a good operating temperature, chemical resistance and bio compatibility. The polymer also prevent mechanical and chemical damage which otherwise could reduce its performance.

The main merit of using fibre optic cable over copper is the ability to transmit data signals with les attenuation aided by their complete immune to Electrical Magnetic Interference (EMI) and Radio Frequencies Interferences [6]. It also has high security as well as long term economy. Durability of the fibre optic cable is threatened by external environmental factors such as mechanical stress and strain due to heavy objects that may be sitting above the ground housing the fibre cable. The fire damages, earth plate movements, high temperatures

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have contributed to the damage of the fibre. Artisanal miners upon discovery of a precious mineral may excavate the cable as there are not concerned about the importance of the fibre. The expansion of roads and towns has also damaged the cable as there are no locators on the ground to direct the excavators. The workers who carry out the excavations are not knowledgeable on how to interpret the maps that may show the layout of these optic fibre on the ground [7].

The study seeks to address mechanical stress and strain problems that affect the fibre cable at Great Zimbabwe University by establishing the Young Modulus, which is an indicator of stiffness or durability using Physics and material science laboratory experiments such as centre span deflection of a simply supported beam (cantilever beam method) and the strain gauge method and, then provide recommendations to protect the cable from future damages.

Problem Statement

Most research has rested more on the internal factors that result in the inefficiency of data transfer ignoring the external factors that may threaten the durability and losses of the fibre. Physics and material science disciplines offer stress testing methods that may contribute to solve some existing problems due to the environment. By establishing the Young modulus constant for typical stress strain levels tolerated by the fibre optic cable, it can help to provide recommendations on the protection of the cable at Great Zimbabwe University where it is used.

Objectives

- To determine the Young Modulus constant for optic fibre cable at Great Zimbabwe University.
- To recommend possible mitigation strategies to LAN fibre optic damage due to stress and strain.

Literature Survey

Fibre optic damage

Optical fibres cables though minute carry vast amounts of data, damage to them can shut down vital communication links in businesses, airports or emergencies [8]. The external forces have a direct impact on the performance of the optical fibre contained in a cable. External factors that contribute to fibre optics damage can either be due to mechanical or environmental effects.

Mechanical effects

Mechanical effects include residual fibre strain, impulse fibre strain, fibre micro bending and fibre macro bending to mention just a few. Optic fibre differs mechanically from copper and steel wires with regards to elastic properties and failure mechanism. Strength is governed by the flaws which are always present under the influence of stress which cause the fibre to weaken [9].

Poor installation

Poor installation practises can result in fibre optic damage. It is as a result of strain due to pulling, bending at the pulley during installation, cutting or breaking of the cable as well as squeezing due to burying machine [6]. This may lead to delayed fracture because of stress corrosion. Aerial cables suffer larger stress along their lifetime than through installation due to shrinkage of the outer jacket and fibres are pushed inside the closure. Contributing factors are the unavailability of trained personnel or too much tension during cable pulling. They are not able to handle the cable well thus male the installation costly [10].

Water and moisture effects on fibre optic

Water causes an irreversible increase in attenuation if it diffuses into the optical fibre material (silicon dioxide). Water molecules also move into the micro cracks, enlarging them and dramatically reducing the life span of the fibre [11]. Optical fibre may fail under stress by propagation of cracks which are accelerated by the presence of humidity. Water expands when it freezes and in a confined space it elongates thereby putting axial stress and compression radial loads upon the optical fibre which may subsequently fail. The generation of hydrogen when water is present may resulting optical loss [12].

Traffic

Vehicles also contribute to optic fibre damage. This could be through vehicle collisions with utility poles which carry or support aerial cable [8] damage could also be as a result of the weight of the vehicles on the surface near which the cables are laid as illustrated below. This can result in transient optical damage due to vibrations on fibre, sheath and joints due to creep [9].

Optic fibre cable construction

A fibre optic cable is made up of a thin, highly transparent strand of glass, or sometimes plastic and its function are to guide light [13]. Fibre optic cable consists of the core, cladding and the buffer as shown in Figure 1.

The core is the centre of the fibre where the light is transmitted. It has a high refractive index than the cladding. The core can be made of either plastic or glass. The plastics that can be used are polymethylmethacrylate or polystyrene. Silica is used to make the glass part doped by either boron or germanium. The cladding is the outside optical layer of the fibre that traps light in the core and guides along even though curves.

It has a lower refractive index than the core. The cladding is normally made of silicon or Teflon [13,14]. The coating is made-up of non-optical layer around the cladding which is made up of 1 or more layers of polymer. The coating protects the optic fibre from physical and environmental damage. The buffer is made up of a hard plastic coating (acrylate or silicon rubber) on the outside of the fibre which can easily be removed when splicing is being done without damaging the fibre. It has higher refractive index than the fibre cladding and absorption loss to prevent the propagation of undesirable modes. It protects the glass from moisture or physical damage during installation and termination [13].

Design of optic fibre cables

When constructing the optic fibre there is great need to consider the following; tensile strength, durability, flammability, temperature range, resistance to the environment, appearance and flexibility. Inorder for the optic fibre to transmit light it needs to be protected

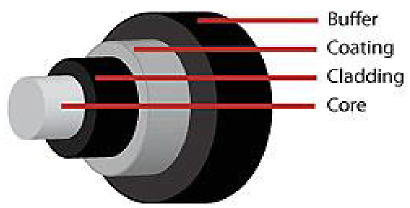

Figure 1: Fibre construction.

from environmental and mechanical effects by either using a loose tube or tight buffer [6] (Figure 2).

Tight buffer

The tight buffer uses plastic cover directly over optic fibre coating. It is able to withstand a lot of great impact and crush without a lot of damage to the fibre optic. The cable is easily affected by sharp bends which may result in optical losses and also has lower isolation for the fibre optic from stresses which would have occurred due to temperature variations. The tight therefore has the following advantages; permits smaller, lightweight designs and provides more flexible crush resistant cable.

During installation the fibre optic cable sustains a lot of loads resulting in tensile stress. This will in turn create an increase in attenuation and failure. Strength members are then used to provide enough strength to the cable as shown in Figure 3. They hold the stress for the fibre optic thereby reducing contraction and expansion and at times act as temperature stabilizers

Burial depth

According to the Fibre Optic Association [12] the depth for burial depends on the type of placement of cable. The minimum recommended depth is shown in Table 1. If the minimum depth is not reached the fibre optic cable needs protection in the form of a concrete slab before backfilling. If this is not done the optic cable will be vulnerable to veld fires and will be susceptible to strain due to heavy load above it. For direct burial there is need to use cable that provides protection against crush and rodent attack.

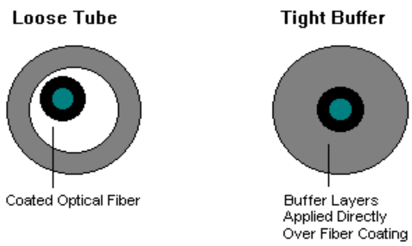

Figure 2: Types of buffers.

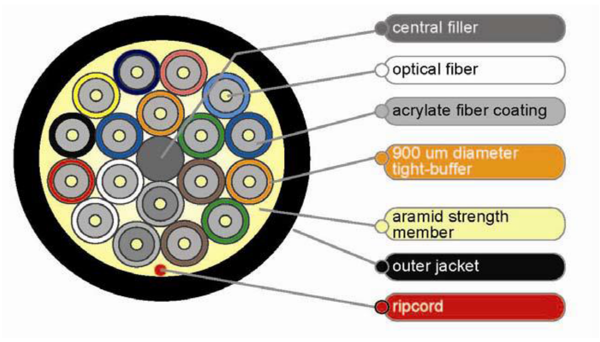

Figure 3: Basic fibre optic cable design (Curan and Shirk).

Type of facility	Depth of cover (m)
Toll and trunk cable	0.76
Feeder and distribution cable	0.60
Drop cable	0.30

Table 1: Recommended burial depth. (OFS, 2013).

Mechanical stress testing

There are various methods for testing mechanical properties of materials. Fibre is a very reliable material but suffers failures due to accidental damage and poor installation techniques. The major tests that could be done on fibre optic and fibre optic cable to determine the failure due to damages include:

- Tensile tests
- Bending tests
- Fracture
- Impact test
- Crush test
- Torsion test

Stress: Strain, (ε) is given by change in length ΔL divided by original length L. It indicates the change in length in a particular direction. Strain is dimensionless.

$$\varepsilon = \frac{\Delta L}{L} \quad (1)$$

Strain: Stress (σ) is given by force F divided by area A on which the force is acting.

$$\sigma = \frac{F}{A} \quad (2)$$

The unit of stress is N/mm^2

The relationship between stress and strain is linked by the equation below where is the young modulus constant E

$$E = \frac{\sigma}{\varepsilon} \quad (3)$$

Young's modulus: The modulus of elasticity or Young's modulus is the slope of the stress strain curve in the elastic region. This relationship is Hooke's law [15] (Figure 4).

Modulus of elasticity is a measured in pascal (Pa). It measures the rigidity of the material. The modulus shows the mechanical properties of a material under load. It is used in stress and deflection calculations [15]. Typical stress strain graph show the trend in Figure 5 as they reach elastic limit and deformation.

For many materials the Young Modulus is constant over a range of

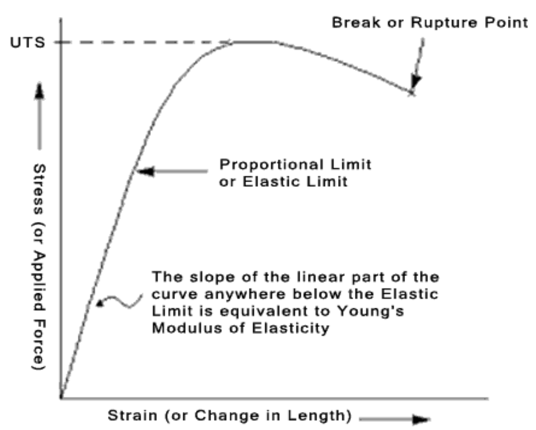

Figure 4: Graph of stress against strain (Cyber physics).

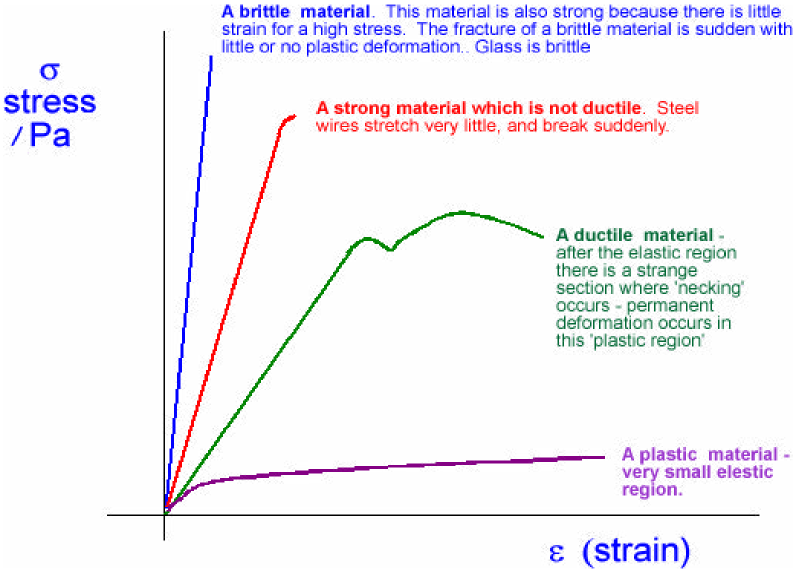

Figure 5: Graph showing the young modulus of different types of materials (cyber physics).

strains e.g. Steel as shown by figure but gradually change as it reaches the various stages. The steepness of the slope determines the strength of the materials. By determining the Young modulus of a material it will help in the material's applicability as this determines how much load it can withstand without failure.

Methodology

Experimental design

The experiment was laboratory based and carried out at room temperature and standard pressure conditions. Two methods were used to determine the young modulus of fibre optic namely

- Method 1: The centre spans deflection of a simply supported beam.
- Method 2 :strain gauge

Geographical site

The experiment was carried out at Great Zimbabwe University located 7.3 km from Masvingo, Zimbabwe. Its geographical position is 20. 6. 11 S and 30. 51. 45 E.

Materials Used

The laboratory instruments used to carry out the experiments were

- Retort stand and clamp, Several weights in grammes (100 g standard weights), metre rule, micrometre screw gauge, mass hangers, 100 g masses, fibre lengths of 1.0 m, 0.5 m and 0.3 m, knife, side cutter, electronic balance, digital thermometer

Optic Fibre Specification: Fibre optic cable 2012, Fibernet FN 1-B118, mm50/125, O (8445, 1515 M, (4 strands of fibre glass in the core) (Figures 6-8).

Theoretical principle for method 1

If a beam is placed horizontally on supported at each end and carries a load at the centre, the beam bends downward. The distance between the original position and its position after bending at different

Figure 6: Fibre optic and its specifications.

points along the length of the beam being maximum at the centre. The difference is called the deflection and is given by the relation y

$$y = \frac{FL^3}{48EI} \tag{4}$$

Where L is the length of beam in metres, F is the load acting on the centre in metres, E is the young modulus of a material in N/mm^2 and is the second moment of inertia defined by

$$I = \frac{\pi d^4}{64} \tag{5}$$

Where d is the diameter of the fibre. By measuring the central deflection, and the applied force the young modulus of the material can be determined using the equation

$$E = \frac{FL^3}{48Iy} \tag{6}$$

If the force F applied is plotted against the deflection Δ, a straight line will be obtained and the gradient of line m is $\frac{d\Delta}{dF}$ and given by:

$$\frac{d\Delta}{dF} = \frac{L^3}{48EI} \tag{7}$$

From eqn. (7), length L is known from measurements, and I is calculated from eqn. (5) as a function of diameter. Then E can be estimated as follows:

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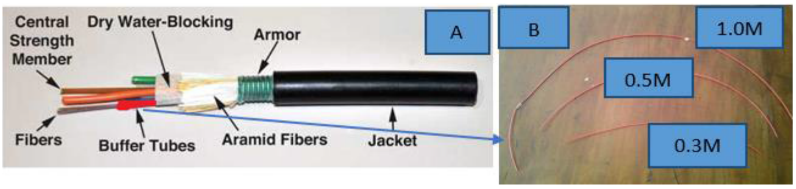

Figure 7: (A) Optic cable with jacket (B) Optic fibre cable with jacket removed.

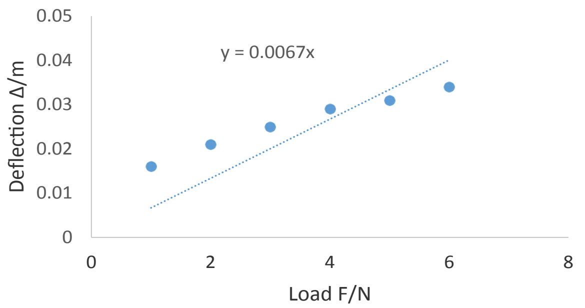

Figure 8: Variation of deflection and load applied for 0.3 m of optic fibre using method 1.

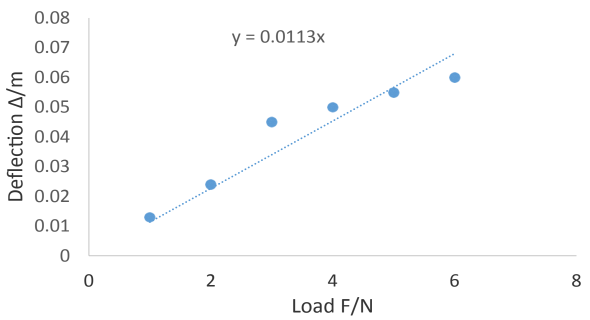

Figure 9: Variation of deflection and load applied for 0.5 m of optic fibre using method 1.

$$E = \frac{L^3}{48I}\frac{dF}{d\Delta} = \frac{L^3}{48Im} \quad (8)$$

Procedure and data collection

The project seeks to estimate Young's modulus constant for the fibre optic cable. The temperature of the laboratory was measured 3 times during the course of the experiments using a digital thermometer and mean calculated. The fibre optic cable in Figure 9 was stripped off the black jacket and the optic fibre in red (Figure 10) was used for both methods measuring it to the required lengths using meter rule and micrometre screw gauge was used to measure the diameter.

Centre span deflection of a simply supported beam

Experimental procedure and data collection for method 1: Parameters to be measured are deflection of fibre optic able as weights are added, mass added and diameter of fibre. The jacket of the optic fibre cable was removed to expose the cladding using a side cutter. The diameter of fibre as measured 3 times along is length and recorded in a table.

The fibre optics was supported at the ends by clamping it and loaded at the centre. Lengths of fibre optic cable used in the experiment were 1 m, 0.5 m and 0.3 m with an additional 0.05 m added for gripping on the clamp was attached to the retort and tightly clamped to avoid it slipping. The 100 g weights were measured on an electronic balance in order to determine the error in the masses. The fibre optics was loaded with a weight in the middle so that it was taut before reading were taken. A box with sand was placed below the weight hanger to avoid accidents from the falling masses. A clamped metre rule was directly opposite the mass hanger very close to the fibre optic cable so that it could indicate the deflection of the fibre optic. The reading on the metre rule was recorded without any load. Weights were added, increasing by 100 g, readings taken at each addition at the same time recording diameter of the fibre. The procedure was repeated for the other lengths and the results were recorded

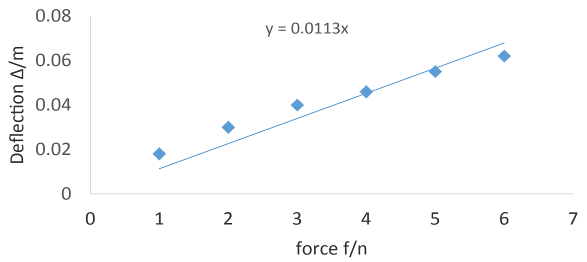

Figure 10: Variation of deflection and load applied for 1.0 m of optic fibre.

Method 2: Measured length for this experiment were 0.2 m and 0.3 m. The fibre was tightly held by the clamp and a mass was hung at the bottom to straighten the fibre. Weights were added gradually at the same time measuring the diameter of the optic fibre. Results were recorded in table. The procedure was repeated for 0.3 m length of optic fibre. The results were presented in the form of table

Precautions:

- Load should not be too high off the floor.
- Place eye rule to get precise reading.
- Avoid parallax and back lash errors during measurement.
- Much care should be taken to minimise the error in taking the measurement of the deflection sine the diameter is very small [16-22].

Results and Discussion

The data obtained on varying mass and deflection is represented in the form of tables and graphs and analysed.

Table 2 shows the diameter of the optical fibre used during the experiment, the fibre optic was measured at 3 different points along its length. The diameter of the optic fibre cable is very small requires a lot precision in measuring. The mean value of diameter was then used in all calculations.

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Table 3 shows the temperature variance when the experiment was being carried out. They are material that is affected by temperature.

Table 4 shows the measured deflection of the loaded optical fibre for 0.3 m, 0.5 m and 1.0 m respectively for the centre span deflection simply supported fibre. Deflection increase with length of optic fibre. There seems to be very little difference in deflection between the 0.5 m and 1.0 m length. The force applied is proportional to the deflection for the 3 lengths measured. The increase in the deflection is very small approximately 1 mm for every 100 g.

Table 5 shows the results obtained when the beam was loaded vertically. As the load is applied the extension also increases. There is very little change on the diameter of the optic fibre which decreases by a margin of 3 mm under a load of 7 N. The stress and strain also increase proportionally with increase diameter and extension respectively

Table 6 shows the results obtained when 0.2 m of optic fibre was loaded using the strain gauge method. There is minimum change in the diameter which in turn affected the stress values. The extension increased by significant amount of 6 mm. 3 N was required to effect a change in extension and diameter. The calculated values of stress and strain increased significantly taking into account the diameter of the optic fibre.

Graphical representation of results obtain using method 1

Figure 8 shows that as the beam is loaded, the deflection also increases. There is a gradual increase from 1 N to 4 N and it is linear but from 5 Nthe increase in load had reduced. The fibre optic seems to have reached the elastic limit. The gradient calculated is 0.0067 m/N.

Figure 9 shows the variation of deflection and load for 0.5 m of optic fibre. The gradient obtained is 0.0113 m/N. The gradient obtained is higher than the one obtained earlier. There is a linear relationship between deflection and load.

Figure 10 shows that there is a linear relationship between deflection and load. The gradient obtained is the same with the one obtained for 0.5 m.

Graphical determination of Young modulus using method 2

Figure 11 shows the linearity between stress and strain. The gradient obtained is the value of young modulus which is given as 64.846 × 10^6 N/m^2

Figure 12 shows the graph obtained when the 0.3 m optic fibre was loaded. The results show that the gradient obtained is very higher when

d_1/×10 m10^{-3} m	d_2/×10^{-3} m	d_3/×10^{-3} m	mean d/×10^{-3} m
2.08	2.15	2.10	2.11

Table 2: Diameter of optic fibre.

$T_{1/°C°C}$	T_2/°C	T_3/°C	mean *T*/°C
19.7	20.9	22.I	21.6

Table 3: Temperature measurements.

Mass/kg	Force F/N	Deflection Δ/m for lengths		
		0.3 m	**0.5 m**	**1.0 m**
0.1	1	0.016	0.013	0.018
0.2	2	0.021	0.024	0.030
0.3	3	0.025	0.045	0.040
0.4	4	0.029	0.050	0.046
0.5	5	0.031	0.055	0.055
0.6	6	0.034	0.060	0.062

Table 4: Results for the relationship between force and deflection for method 1.

Mass/g	Force F/N	Extension Δ*L*/10$10^{-3}$ m	Diameter m/×10^{-3} m	Stress × 10^6 N/m^2	Strain
0	0	0.00	2.10	0.0	0.000
100	1	1.00	2.10	0.289	0.003
200	2	2.00	2.10	0.577	0.007
300	3	3.00	2.09	0.874	0.010
400	4	4.00	2.09	1.160	0.013
500	5	4.00	2.08	1.470	0.015
600	6	5.00	2.08	1.766	0.017
700	7	6.00	2.07	2.08	0.020

Table 5: Results obtained using the 0.3 m optic fibre using the strain gauge method.

Mass m/g	Force/N	Extension Δ*L*/10^{-3} m	Diameter d/×10^{-3} m	Stress × 10^6 N/m^2	Strain
0	0	0	2.11	0	0.000
100	1	0	2.11	0.286	0.000
200	2	1	2.11	0.572	0.005
300	3	3	2.10	0.866	0.015
400	4	4	2.10	1.120	0.020
500	5	4	2.09	1.460	0.020
600	6	5	2.09	1.750	0.025
700	7	6	2.08	2.060	0.033

Table 6: Results obtained using 0.2 m optic fibre using the strain gauge method.

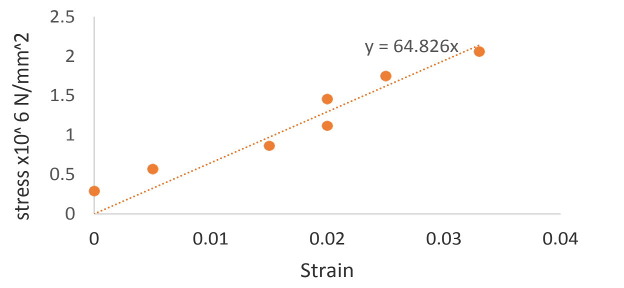

Figure 11: Stress vs. strain graph for 0.2 m optic fibre using the strain gauge.

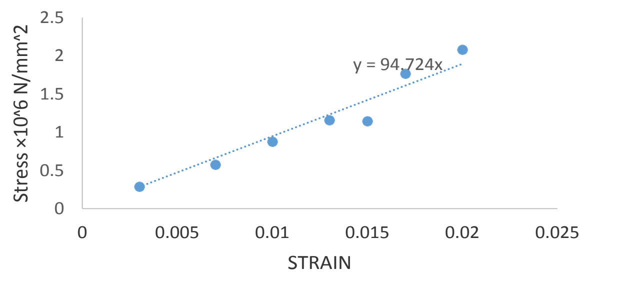

Figure 12: Stress vs. strain graph for 0.3 m optic fibre using the strain gauge method.

comparing with 0.2 m length of optic fibre. The gradient is 94.724×10^6 N/m^2 and it represents the value E.

Calculated values of Young modulus

Table 4 shows the calculated Young modulus for the 2 methods used. The centre span deflection method of a simply supported beam produced high values of E. The values of E increased with length. The value obtained at 0.3 m using the centre span deflection simply supported beam method is with the stipulated value of 72-85 GPa and the other values at 0.5 m and 1.0 m indicate that the Young modulus is length depend. For the strain gauge method the value of the young modulus was lower compared to the centre span deflection of a simply supported beam method. The value of young modulus also depend the method used.

Computation of errors

Table 5 shows the calculated values of the error incurred using the centre span deflection for a simply supported beam method. The errors are very small within 0.003%. This could have risen from the sensitivity of the instruments used. The deflection was very small and was very difficult to compute with the eye.

Table 7 shows the error in the measuring instruments used as well as the calculated error as the length increases the error also increases. The error produced is small within 0.3% of the calculated value.

External environment effect on the cable

Small car vehicles weight is around 2300 kg and a group of 50 students with an average weight of 70 kg weigh 3500 kg and these are significant weights to have an effect on the cable. However the weight is distributed over a large area and not necessarily concentrated. In addition the land on which the cable is buried exerts an equal and opposite or upward force according to Newton's 3rd law of motion unless the ground on which the object is resting is not rigid. This cancels out the weight and pose no threat to the cable. Non rigid ground gives in to the weight and pose a threat to the breaking of the fibre optic cable, therefore there is need to make the ground rigid by adding concrete layer (Tables 8 and 9).

Conclusion and Recommendations

The experimental values of Young modulus obtained using method 1 for 0.3 m, 0.5 m and 1.0 m were 86,6 GPa, 226.9 GPa and 177.6 GPa respectively. The theoretical value of E for the fibre optic used is between 72-85 GPa. The value obtained for the 0.3 m is within the range but as the experimental length increases the value of E also increase. The calculated percentage error was 0.003 % which was very minimum. The values of E obtained using method 2 were 64.8 MPa and 94.7 MPa for 0.2 m and 0.3 m of fibre optic used respectively. The percentage error was 0.3% which was a bit too high compared to the one obtained using method 1. It can be safely concluded that the value of Young modulus depends on the length of fibre optic as well the way the fibre optics is loaded i.e. horizontal or vertical. Hence the results obtained were quite realistic taking into account the equipment used to determine E in this project. Deviation of E could have been effected by the cable material. Theoretical values of E used were obtained from measuring the value of 1 strand of fibre optic. In this experiment, the fibre optic used had 4 strands of fibre optic which were coated by a buffer material (acrylate). The combination of these 2 different material had an effect on the results. Temperature has an effect on the value of E. The experiments were carried out at approximately 20.2°C, which was slightly below room temperature hence had little effect on the value of Generally there is a decrease in young modulus with temperature since it is easier to stretch the atomic bonds. In order to get more precise values more samples of fibre optic length could have been used to reduce errors. When using the centre span method the value was very high and when using the strain gauge the value small. In each method, as the length increases the value of the young modulus also increases. The errors obtained in each method are very minimum showing that the experiment was well articulated to minimise errors since the deflection were very small. It can safely be concluded that young modulus varies with length and the method used. For short length using the centre

Method	Length(m)	E(N/m^2)
Method 1	0.3	8.67×10^{10}
	0.5	2.34×10^{11}
	1.0	1.78×10^{11}
Method 2	0.2	6.48×10^7
	0.3	9.47×10^7

Table 7: Calculated values of Young modulus E.

Instrument	Quantity	Error Δ
Metre rule	Length	$\pm 1 \times 10^3$ m
Micrometre screw gauge	Diameter	$\pm 1 \times 10^{-5}$ m
Computated E	0.3 m	$\pm 3 \times 10^6$ N/m^2
	0.5 m	$\pm 5 \times 10^6$ N/m^2
	1.0 m	$\pm 4 \times 10^6$ N/m^2

Table 8: Error computation for Young modulus using method 1.

Instrument	Quantity	Error Δ
Meter rule	Length	$\pm 1 \times 10^{-3}$ m
Micrometre screw gauge	Diameter	$\pm 1 \times 10^{-5}$ m
Electronic balance	Mass	$\pm 1 \times 10^{-3}$ kg
Commutated E	0.2 m	$\pm 2 \times 10^6$ N/m^2
	0.3 m	$\pm 3 \times 10^5$ N/m^2

Table 9: Error computation for young modulus using method 2.

span deflection of fibre the value obtained is very much nearer to the stipulated values of Young modulus of approximately 72-85 GPa for E glass fibre used in this experiment (FOA.2015). This is consistent with what was expected. As the length of optic fibre increases it expected for the value of young modulus to increase proportionally. Taking into consideration that 4 strands of optic fibre were in the buffer which is made of polyethene, the combined effect of the 2 materials could have an effect on the value of Young modulus hence the results obtained are justified.

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