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Research Article

Development and Evaluation of Fire Resistant Railway Signalling Cable

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Abstract

The railway signalling cable is designed for remote control and teletransmission in underground railway networks. It is very critical situation that the railway signalling cable continues to transmit data in the event of a fire. In this study, the fire resistant test performance of railway signalling cable has been developmented and evaluated via experimental research. A standard railway signalling cable generally consists of conductor, insulation, laying-up, wrapping, screen, inner sheath, armour and outher sheath. The mica tape was added as one layer with 30% overlapping to produce desired fire resistant cable. First step, the railway signalling cable produced used only mica tape used, results show that the cable with mica tape is successful at 110 V. Also, it is not bad for the 250V as it seen the test results. After having non satisfied results, glass tape was added additionally over inner sheath (instead of PP tape) for better results for higher voltage values. After redesign of the cable with addition of glass tape over inner sheath, better results were expected but the results were not as good as expected. Only at 250V appropriate results were achieved according to both IEC 60331 – 21 & 60331-2 standard. When we examined the situation, we saw that the cable was flattened a bit after the new-design. Then, the re-production of the new design cable (mica + glass tape) is been planned without any rework process. All results show that the new design railway signalling cable is resistant to fire tests according to IEC 60331-21, IEC 60331-1&2 up to 1000V as shown in the paper.

Keywords: Cable Production, Railway Signalling Cable, Fire Resistant Cable, Fire Resistant Test, IEC 60331-21 and IEC 60331-1&2

Yangına Dayanıklı Demiryolu Sinyalizasyon Kablosu Geliştirilmesi ve Değerlendirilmesi

Öz

Demiryolu sinyal kablosu, yeraltı demiryolu ağlarında uzaktan kumanda ve tele iletim için tasarlanmıştır. Bir yangın durumunda demiryolu sinyalizasyon kablosunun veri iletmeye devam etmesi çok kritik bir durumdur. Bu çalışmada, demiryolu sinyalizasyon kablosunun yangına dayanıklılık test performansı deneysel araştırma yoluyla geliştirilmiş ve değerlendirilmiştir. Standart bir demiryolu sinyalizasyon kablosu genellikle iletken, izolasyon, büküm, ekran, iç kılıf, zırh ve dış kılıftan oluşur. İstenen yangına dayanıklı kabloyu üretmek için iletken üzerine helisel olarak uygulanan mika bant %30 bindirme ile bir katman olarak eklenmiştir. İlk prototipte sadece mika bant kullanılarak üretilen demiryolu sinyalizasyon kablosunun 110V'ta sonuçlarının uygun olduğu görülmüştür. Aprıca test sonuçlarında görüldüğü gibi 250V'da sınır değerde olduğu görülmüştür. Tatmin edici olmayan sonuçlar alındıktan sonra, daha yüksek voltaj değerleri için daha iyi sonuçlar için iç kılıf üzerine ek olarak cam bant eklenmiştir. Kablonun iç kılıf üzerine cam bant eklenerek yeniden tasarlanmasından sonra daha iyi sonuçlar beklenmesine ragmen sonuçlar beklendiği gibi elde edilememiştir. Hem IEC 60331 – 21 hem de 60331-2 standardına göre sadece 250V'da uygun sonuçlar elde edilmiştir. Detaylı inceleme yapıldığı zaman yapıda fiziksel bozulmalar olduğu görülmüştür. Daha sonra yeni tasarım (mika+cam bant uygulamalı) yeni prototip olarak üretilmiştir. Tüm sonuçlar, yeni tasarım demiryolu sinyalizasyon kablosunun yayında gösterildiği gibi IEC 60331-21, IEC 60331-1&2'ye göre 1000V'a kadar yangın testlerine dayanıklı olduğunu göstermektedir.

Anahtar Kelimeler: Kablo Üretimi, Demiryolu Sinyal Kablosu, Yangına Dayanıklı Kablo, Yangına Dayanıklılık Testi, IEC 60331-21 ve IEC 60331-1&2

1. Introduction

The underground railways, the other words subways, are indispensable means of transportation in modern city life. The railways, which are offered as a solution to traffic jam, encounter unexpected situations from time to time. The most important problems are eartquate, fire and others reasons. It is vital that data transmission continues at the time of such unexpected simulations. Specially developed cables are used for data transmission. The railway signalling cables is designed for remote control and teletransmission in underground railway networks. It is very critical situation that the railway signal cable continues to transmit data in the event of a fire. The other Words, Circuit integrity cables are designed to provide uninterrupted power supply to important services in the event of fire, to allow for safer evacuation and fire-fighting effort (I. Ivanov, G. Alexander, 2015). A standard K23 cable design structure is given in Figure *1*.

Figure 1

The informaiton regarding the parts indicated in the *Figure 1* is presented blow:

1. Conductor: solid annealed bare copper to IEC 60228 (Class 1), Diameter: 0.6 mm, 1.0 mm and 1.2 mm

2. Insulation: Polyethylene

Laying-Up: Twisted pairs/quads, two/four insulated conductors twisted into a pair/quad according to poduct

3. Wrapping (Binder Type): Several layers of plastic tape + Rip cord

4. Screen: On side copolymer coated Aluminum foil Bonded to the inner sheath. Tinned copper wire shall be longitudinally Contact to metal side of tape as drain wire.

5. Inner Sheath: Low smoke zero halogen compound, inner sheath colour: black

6. Bedding: Protection (PP cell) tapes

7. Armour: Two layers of galvanized steel tape armour, thickness: 0.2 mm

8. Outher Sheath: Law smoke zero halogen compound, outher sheath colour: blak

In 2010, the cable overseatch selection: the right material for the right aplication was studied by Simon J. Sutton, Theo Geussens and Kurt Bolz. In this study, the range of oversheath materials was evaluated and the most appropriate the particular solutions has been focused. Modern hologen free flame retardant (HFFR) is used most. The strongest alternative to this material is PVC (Simon, J. Sutton, Theo Geussens, Kurt Bolz, 2010:1). In Mechanical cractreristics for the medium voltage cables sheating was improved with HFFR materials was studying in 2003. In the study, the tensile strength elongation at break, tear Resistant, abrasion Resistant on cable, oxygen index and acid gas tests were conducted by authors (Jacint ROVIRA, Montserrat PRAT, Juan de Dios MARTÍNEZ, 2003:59). The other study for the different designs for low-fire-hazard cables were tested under conditions the fire test speciefied in IEC 60331-21 was perfomed by R. Polansky and M. Polanska in 2015. In the study, The measurement set-up adapted to enable insulation Resistance measurements throughout the entire fire test. The results of the tests demonstrate that the measurements of the insulaiton Resistance together with the use of thermocouples placed near the cable sheath and between the insulated cable cores can yield important insight into the processes (R. Polansky, M. Polanska, 2015-57)

In this study, the standard K23 cable design was used first step. The sdandard cable structure consists of conductor, inner sheath, armour, outher sheath and mica tape layers. The inner sheath and outher sheath material is the HFFR. The Halogen Free Flame Retardant (HFFR) materials are used in ever more areas and under more demanding environmental conditions. Especially, the ambient temperature, short circuit temperature, fire behaviour, smoke emission, toxicity/acidity, insect Resistant and bending are very important effect for the cables. Amongst the major markets where flame retardants are required, the industries dealing with constuction, electrical and electronic components and transportation are the three of rgeatest importance (Shui-Yu Lu, Ian Hamerton, 2002: 27). In the second step, test procedures were carried out by applying glass tape to the cable structure. As a result, evaluations were made by analyzing the test results.

2. Material and Method

2.1. Cable Structure Materials

HFFR, mica tape, glass tape, pure copper and polyethylene materials were used for signal cable design production in this study. Glass tape was applied especially against fire resistance and the results were observed. Mica tapes are important fire resistant materials currently used in cables. Muscovite was used as the main material of mica tape. The glass tapes are widely used for power and control cables, instrumentation and signalling cables because of its excellent flame Resistance. Some technical properties of galss tape are high tensile strentgh, strong Resistance to radiation, acid and alkali, non-toxic under hig temperature, excellent flexibility, heat Resistance up to 950 °C. Chemical composition of the glass tape material used in this study is given in Table 1. In this study, the fire resistant effect of only the use of mica tape and additionally the application of glass tape on railway cables was investigated.

Table 1 Composition of glass tape ((“Glas Tape Techical Properties”, 2021)

SiO_2	Al_2O_3	CaO	MgO	B_2O_3
54.1 ±0.5%	14.6 ±0.4%	16.6±0.3%	4.6±0.3%	8.8±0.5

2.2. Test Method

In this Project, signal cables have been subjected to many tests. In experimental studies, it is extremely important to experiment according to standards. The relevant standard in this area is the IEC standard. IEC, International Electrotechnical Commission, is an international standards organization that prepares and publishes international standards for all electrical, electronic and releted technologies (“IEC”, 2021). The standard for the fire resistant of the cables is included in the IEC 60331 standard. This test standard is for verifying the Resistant to fire alone of electrical cables used for wiring and interconnection where it is required to maintain circuit integrity under fire conditinos. It is important for communication that electrical or signal cables maintain their circuit integrity under fire condition. IEC 60331-1:2018 standard was used in this paper. This standard specifies the test method for cables. Especially the cables which are required to maintain circuit integrity when subjected to fire and Mechanical shocuk under conditions. According to this standard, the rated voltage not exceeding 600 V / 1000 V, includign those of rated voltage below 80 V, metallic data and telecom cables and optical fibre cables. The diameter of the tested cable must be greater than 20 mm (“IEC 60331-1:2018”, 2021). The other standard for the experiments was IEC 60331-2:2018. The standard specifies the test method for cables which are requried to maintain circuit integrity whan subjected to fire and Mechanical shock. The difference from the other standard is that the cable diameter is less than 20 mm (“IEC 60331-2:2018”, 2021). The other standard is the IEC 60331-21. The standard specifies the test procedure and gives the performance requirement, including a recommended flame applications time, for cables of rated voltages up to and including 0,6/1,0 kV required to maintain circut integrity when subjected to fire under spesified conditions (“IEC 60331-21:1998”, 2021). Difference between IEC 60331-21 and IEC 60331-23 standard Covers electric data cables which have no rated voltage and are used for extra low voltage circuits. In this study, all fire tests were carried out on the devices of Nexans Turkiye Company in accordance with the IEC standards.

According to IEC 60331 standards, 90+15 minutes rule is appiled as test success criteria. That is, in the test proceses performed according to the IEC 60331 standard, the signal cable must last for a minimum 105 minites and transmit data uninterruptedly. The test results blow the value will be considered unsuccessful. If a test operation fails, a retest is performed under the same conditions. If the test is succsessful in the retest process, the product is considered to have passed the test operaiton. This process can be repeated several times.

2.3. Experimental Design

Different designs for railway signal cables were tested under conditions similar to those of the fire test specified in IEC 60331-21, 23, 1 and BS EN 50289-4-16:2016. Experimental research technique was used as a method in the project study. The study consists of three stages. In the first stage, normal cable structure was used and tested. In this step, mica tape was added as one layer with %30 overlapping to produce desired fire resistant cable. After the experiments of first step were applied, the second step was started. In the scond step, glass tape were added additionally over inner sheath. Then, the second step experiments were carried out. Altough the good results were expected, especially high test voltage, the results were not satisfactory. Therefore, the cable with glass tape was redesigned and the experiments were performed again. As seen this study, the basic experimental design approach was used, and the results of experiments were evaluated.

In the experimental design, we used the factors according to standard cable structure. The study was carried out by changing the structural changes and the applied test currents. The important variable in the study is whether there is a glass tape. The effect of glass tape application on fire resistant is one of the important results examined. Additionally, the test voltajj (V) was the other important parameter. It is the criterion of success in the test that the cable maintains its properties at the desired time at the temperatures specified in the test standards of IEC. The schematic vievew of experimental system is shown in Figure 2.

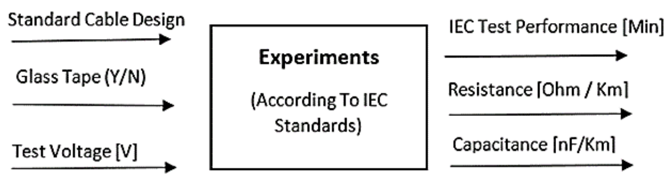


Figure 2 The Experimental System

3. Results and Discussion

3.1. Results of Standard Cable Design

The results of the standard K23 design, which is the first step in the experimental study, are examined and listed in Table 2. As can be seen from the Table 2, the cable has succsessfully passed the test at 110 V test voltage level. But it is seen that the test process gives the results at the limit value (90+15Min] at 250V test voltaj. At 500 V test voltaj, the test failed within half of the limit value. When the test samples were examined after test, it was observed that there were structureal deteriorations. The results of the examinations are given in Figure 3.

(a) (b)

Figure 3 The Structural View of cable after test operations; a) 250V appiled state, b) 500V applied state

3.2. Results of New Cable Design With Glass Tape Appiled

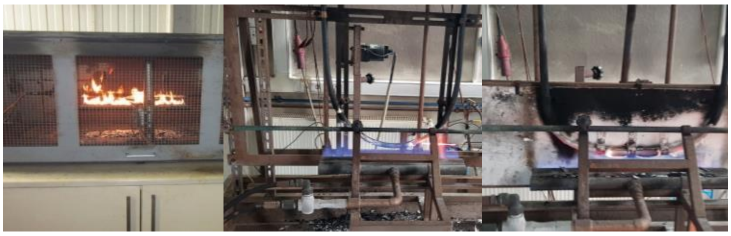
The results when glase tape is added additionally over inner sheath is given in Table 3 and Table 4. According to the Table 3, it is seen that the test failed at 500V and 300V test voltage. However, when the test results is analyzed, it is seen that there is a problem. Because of this situation, the cables were examined in detail after the test operations. The Deformation region in the structure after test (IEC 60331-23) is given in Figure 4.

Figure 4 The Deformation in the structure after the test operations at 300V test voltaj

After redesign of K23 signal cable with addition of glass tape over inner sheath, better results were expected. But the results were not satisfactory enough. Only at 250V appropriate results were achived according to both IEC 60331-21/23 and 60311-2 standard. When the examine this situaiton, it was observed that the cable was flattened a bit after the new-design. In new design process, previous cable is re-worked as removin sheath and armour, the n applying glass tape over inner sheath, then armouring and sheating again. It has been determined that this situation affects the test results and prevents the desired results from beign obtained.

3.3. Results of Re-Produced New Cable Design With Glass Tape Applied

Re-produced cables have been tested according to IEC 60331-21/1/2 standard and have been tested at test voltages of 100, 250, 300 and 500V. Afterwards, it was tested at 1000V test voltage and the results are given in Table 5. The figure of the applied tests are given in Figure 5. As expected, the desired results are taken on the new cable. Test are successfull according to IEC 60331-21, 1-2 at 1000V test voltaj. The last cable is also tested according to BS EN 50289-4-16:2016 and results are satisfactory, and the variation of Capacitance values are less then %30 test criteria. The Resistant measurement and Capacitance measurement during test operation is given Figure 6 and Figure 7.



(a) (b) (c)

Figure 2 The figure of the applied tests; a) IEC 60331-21, b) ıec 61331-1, c) IEC 60331-2 test

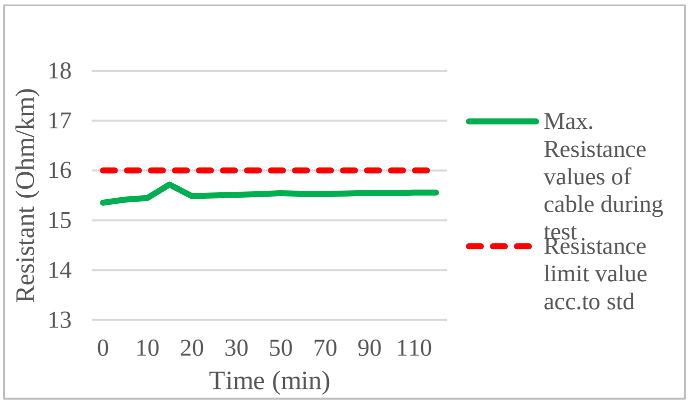


Figure 3 The results of resistant mearusement during test IEC 60331-1

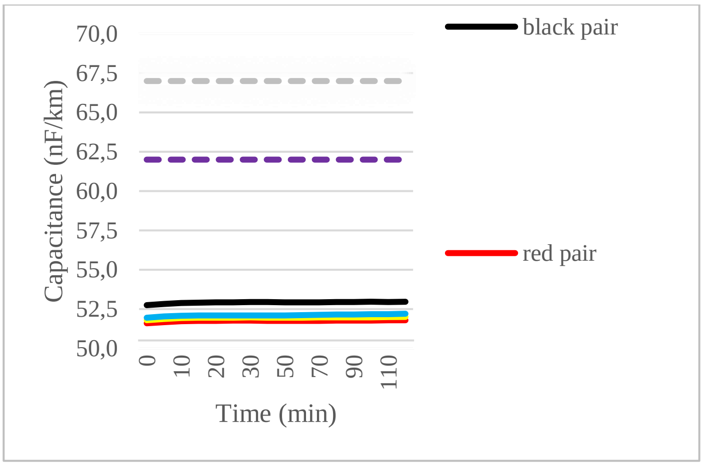


Figure 7 The results of resistant mearusement during test IEC 60331-1

4. Conclusions and Recommendations

Fire resistant tests carried out by applying glass tape to the standard Railway signalling cable structure. The test results were compared and evaluated before and after the glass tape was applied. The IEC standard was used in the implementation of the test procedures and the test equipment within the company of Nexans, which complies with the standard, was used. Planning was made for the experimental study, experiments were carried out and the results were examined. The results showed that the application of glass tape in signal cables significantly increased the fire resistant. It has been understood from the study that the glass tape application has gained significant advantages in terms of both IEC 60331 tests and resistant and capacitance tests (BS EN 50289-4-16:2016) in terms of fulfilling the task of signal cables in important situations such as fire. As a result of the study, glass tape can be used in signal cable production, but the application of mica and glass tape at the same time increasing the cable diameter should be evaluated in terms of standards. In future scientific studies, the advantages and disadvantages of glass tape applications with different properties can be evaluated in terms of fire resistant, as well as studies on cable diameter can be made. Again, fire resistant cable development Studies can be carried using different innovative materials and different applications can be performend in this filed. In other Studies to be done in the future, a more comprehensive reseach can be done wtih more Production and product Parameters by using the statistical experimental design method.

Table 1 The results of standard cable design tests (IEC 60331-23)

Cable Type	Inner Sheath	Outher Sheath	Thickness [Cm]	Mica Tape	Glass Tape	Test Voltaj [V]	Duration of Test [Min]		
K23 4P1,2	HFFR	HFFR	1,54	Y	N	110	90+15	90+15	90+15
K23 4P1,2	HFFR	HFFR	1,54	Y	N	250	**88**	**90+0**	
K23 4P1,2	HFFR	HFFR	1,54	Y	N	500	**45**		

Table 2 The results when galss tape is added additionally over inner sheath (IEC 60331-23)

Cable Type	Inner Sheath	Outher Sheath	Thickness [Cm]	Mica Tape	Glass Tape	Test Voltaj [V]	Duration of Test [Min]		
K23 4P1,2	HFFR	HFFR	1,70	Y	Y	500	**88**	90+15	**68**
K23 4P1,2	HFFR	HFFR	1,70	Y	Y	300	**90+0**	**20,15**	90+15
K23 4P1,2	HFFR	HFFR	1,70	Y	Y	250	90+15	90+15	
K23 4P1,2	HFFR	HFFR	1,70	Y	Y	110	90+15	90+15	

Table 3 The reseluts when glass tape is dded additionally over inner sheath (IEC 60331-2)

Cable Type	Inner Sheath	Outher Sheath	Thickness [Cm]	Mica Tape	Glass Tape	Test Voltaj [V]	Duration of Test [Min]	
K23 4P1,2	HFFR	HFFR	1,70	Y	Y	500	**21**	**14**
K23 4P1,2	HFFR	HFFR	1,70	Y	Y	300	120+15	120+15
K23 4P1,2	HFFR	HFFR	1,70	Y	Y	200	120+15	120+15
K23 4P1,2	HFFR	HFFR	1,70	Y	Y	110	120+15	120+15

Table 4 The results of re-produced new cable design with glass tape applied

Test	Cable Type	Thickness [Cm]	Mica Tape	Glass Tape	Test Voltaj [V]	Duration of Test [Min]		
IEC 60331-21	K23 4P1,2 BLACK	1,32	Y	Y	1000	90+15	90+15	90+15
IEC 60331-1	K23 4P1,2 BLACK	1,32	Y	Y	1000	120+15	120+15	120+15
IEC 60331-21	K23 4P1,2 BLACK	1,32	Y	Y	1000	84	120+15	120+15

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