# Case Study on using different insulators for Indian Railways network, performance analysis of in–service composite insulators and future Recommendations

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***Abstract-* The role of insulators in the Indian Railways Traction system is very critical for the efficient functioning of the whole network. In this work a detailed case study has been done of the Indian Railways Traction network across various zones of the country to understand their requirements and preference of choice for their application namely composite/porcelain. Survey indicated Indian railways have realized significant benefits with the use of composite on multiple aspects. To further understand the healthiness of the composite insulators that have been in service for a considerable time, two of them were removed and tests on mechanical, electrical and material aspects were performed in third party NABL accredited labs. This further confirmed the healthy nature of in-service composite insulators.**

## I INTRODUCTION

High Voltage Insulators in an electrical system perform the dual role of providing mechanical support and electrical isolation. In general the common materials used for this application are silicone rubber insulators, porcelain and glass. The Indian railways network is a vast system of approximately 67,000 route km of which about 33,000 route kms are already electrified using either Silicone rubber or porcelain insulators. Rapid electrification plans are currently underway and the benefits that the Indian Railways has realized with Silicone rubber/Porcelain, environmental demands are likely to determine their choices for the future projects.

## II. GLOBAL TREND

Conventionally HV insulators that were used through out the world were primarily Glass/Porcelain until late 1960's. Numerous issues that were experienced throughout the world primarily on pollution related failures led to the development of composite insulators in late 60's. Globally numerous countries like China, Switzerland started using the composite insulators for railway network in late 70's. In India use of composite insulators has completed 25 years of successful operation with Tata power installing them in 1993. Figure 1 shows its successful use till date in Railway Tunnel since 1979. The HV composite insulators are used for catenary support and tension applications in tunnels as shown in Figure 1. It is to be noted that the frequency of trains exert very high mechanical loads and high pollution levels [1-14].

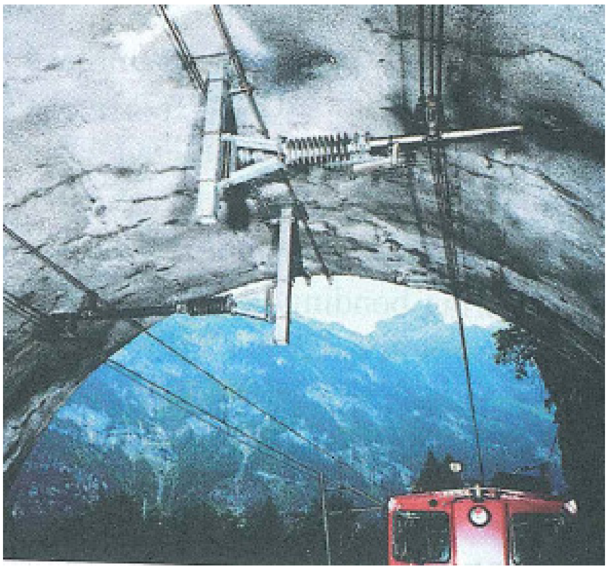

Figure 1: Applications of Composite insulators in European Railways network – Lotschberg tunnel [8]

With the technology maturing in the last few decades the initial concerns that were present have been duly addressed. When we observed the Global usage as shown below in Figure 2, it can be observed that considering the introduction of composite to the world market in late 80's it occupies a significant percentage today in the global preference. Numerous reasons that have been attributed for this dominance in the Global market include superior contamination performance due to hydrophobic nature, light weight up to 90 % over porcelain, maintenance free, vandal and shatter proof material unlike porcelain. Further benefits include higher Short Circuit loading reliability, superior seismic performance, high strength to weight ratio, a very compact design addressing the right of way concerns in today's ever-growing congested network. The benefits of composite insulators have been realized widely across as their use is rapidly increasing in line insulation system, substation applications of post, hollow core in CTS, PTS and so on.

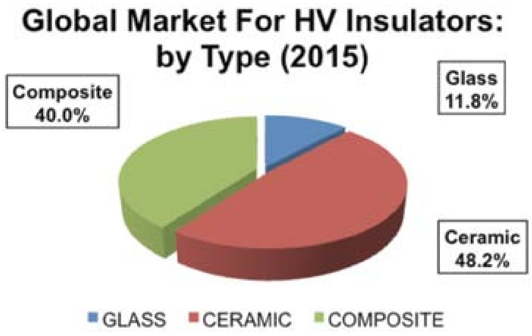


Figure 2: Recent survey on use of different insulating materials demonstrate the rapid growth of composite use globally

III INDIAN RAILWAYS NETWORK – HV INSULATORS USE

Composite Insulators, manufactured with silicone rubber housing, have been in use in Indian Railway Traction system since 2005. Indian railways network typically uses three major types of insulators using composite and porcelain material they are: Stay Arm, Bracket tube and 9 T insulators. Insulators are used in vertical, horizontal and at angled positions as can be seen below.

Figure 3: Use of HV insulators for Railway applications; example: 1

Currently several thousands of HV insulators are used by the Indian Railways in the application of about 33,000 route kms of their traction network. With the rapid industrialization, and significant increase in the pollution levels throughout India in the recent years lot of replacements are planned to ensure efficient performance in demanding environment. Also, on the other hand lot of new projects are taking places where in insulator material selection is very critical for successful operation in the coming years. In this context a detailed survey was undertaken as it can throw some light on what benefits that Indian railways has realized over several years on the use of different materials for their applications.

Figure 4: Use of HV insulators for Railway applications; example: 2

### *A. SURVEY ACRSOSS VARIOUS ZONES OF INDIAN RAILWAYS NETWORK*

The survey was aimed to understand the operation of Indian Railways from a reliability point of view the issues faced by them and subsequently the role of insulators in the same. There are totally 17 zones in the Indian Railways that cover the whole country. In order to ensure a very good understanding of the benefits that are realized the survey was performed across a widespread region that covered 10 zones and 19 locations across the railway network. The survey was ensured to cover generic points, qualitative and quantitative points and a questionnaire was framed accordingly. The following provides a summary of questions:

Generic questions:

- Temporary trippings per month with reasons
- Season of trippings
- Cause of permanent trippings
- Adherence to storage, transport and installation guidelines
- Any other Specific concerns faced by Indian Railways

Qualitative questions

- Use in vandal prone areas
- How effective the insulator weight plays a role
- Transportation related comparison
- Ease of installation/replacement
- Maintenance related comparison

- Functioning in highly contaminated locations eg: cement factory
- Overall preference of field persons - polymer vs porcelain

Quantitative questions:

- Approx. number of polymer/porcelain insulators in the jurisdiction of Senior Sectional Engineer
- Number of failures (F/O, breakage)
- Number of yrs. in service
- Time for replacement of existing with new insulator
- Time spent on maintenance (cleaning)
- Time and labour required to detect failure
- Frequency of inspection
- Satisfaction level on lowest (1) to at most (10)

The summary of survey findings are provided in Table 1.

Table 1: Summary of survey findings

| **S.No** | **Location** | **Railway Zone** | Polymer/Porcelain /Both Preference |
|---|---|---|---|
| 1 | Sanat Nagar | SCR | Polymer |
| 2 | Moulali | SCR | Polymer |
| 3 | Secunderabad | SCR | Polymer |
| 4 | Kacheguda | SCR | Polymer |
| 5 | Guntur | SCR | Polymer |
| 6 | Vijayawada | SCR | Both |
| 7 | Sholapur | CR | Porcelain |
| 8 | Mumbai | CR | Polymer |
| 9 | Mumbai | WR | Both |
| 10 | Vadodara | WR | Polymer |
| 11 | Delhi | NR | Both |
| 12 | Lucknow | NR | Polymer |
| 13 | Allahabad | NCR | Both |
| 14 | Danapur | ECR | Both |
| 15 | Howrah | ER | Polymer |
| 16 | Howrah | SER | Both |
| 17 | Kharagpur | SER | Both |
| 18 | Bhubaneswar | EcoR | Porcelain |
| 19 | Vizak | EcoR | Porcelain |

Summary demonstrated the preference of polymer over porcelain, as out of 19 locations, Polymer was preferred in 9; Porcelain was preferred in 3 and both were preferred in 7 locations. Based on the survey outcome Table 2 calculations were made that would throw some light in to the expenses spent in the use of porcelain insulators in the maintenance perspective considering 40 years of service life.

In Table 2, data present in the first three rows is an average figure derived based on the feedback taken across several locations in several zones.

Table 2: Calculations of maintenance cost of porcelain insulators

| | |
|---|---|
| Approximate number of porcelain insulators (about 250 route km) | 6700 |
| Approximate time to clean insulator in minutes | 2 |
| Time spent per insulator additionally considering tower car movement in minutes | 4 |
| Total time spent in terms of man hours with 3 men operating | 2010 |
| Total time spent for 3 times in a year cleaning in terms of man days (8 hours per day) | 754 |
| Converting to man months with 25 days a month | 30.2 |
| Assuming salary of Rs 30,000 per month | 906000 |
| Approx. life cycle cost per insulator considering per insulator cost of Rs 1800 for a period of 40 years of life | Rs 7209 (4 times insulator cost) |
| Considering electrified 30,000 route km the maintenance per year | Rs. 109 million |
| Considering 40 yrs life of porcelain total to be spent on maintenance without considering inflation | Rs. 4360 million |

*B. TESTING OF IN-SERVICVE INSULATORS*

As an extension of the above survey it was of interest to understand the condition of in-service composite insulators that has been in use for at least over 5 years. In this context SCR provided two samples of Deccan make (one stay, one bracket) duly signed on insulators. The creepage distance of the insulators both Stay Arm, Bracket was 1050 mm CD. This corresponds to 20 mm/kV for the highest rated voltage of 52 kV. These insulators have been in operation since 2010 (over 8 years of service). Testing on these insulators was taken up to assess the condition.

**Details of testing:**

In order to assess the true condition of the sample it is ideal to test the same on the aspects of electrical, mechanical and material characteristics. Following tests were conducted at third party independent labs.

Mechanical test (Bracket Insulator):

- The sample was tested for bending moment

Material tests:

- Sample tested for silicone content
- Sample tested for specific gravity value

Electrical tests (Stay arm):

- Sample tested for 15 shots of positive and negative impulse to observe BIL withstand value
- Sample tested for wet power frequency withstand voltage

The summary of the test results are provided in Table 3.

Table 3: Summary of test results of in-service insulators

| Test details | Requirement | Actual | Comments |
|---|---|---|---|
| Bending Moment (Mechanical test) | 200 kgf.m (min) | 413.78 kgf.m | Test passed |
| Silicone content (Material) | 30 % (min) | 31 % | Test passed |
| Specific Gravity (Material) | 1.52 to 1.58 g/cc | 1.56 g/cc | Test passed |
| Dry Lightning Impulse Voltage withstand test (Electrical) | (+ve) 240 kV<br>(-ve) 260 kV | Withstood<br>Withstood | Test passed |
| Wet Power Frequency Withstand test (Electrical) | 100 kV (RMS) | 100 kV (RMS) | Test passed |

## IV. INFERENCES FROM SURVEY, LIFE CYCLE ESTIMATE AND TESTS OF IN-SERVICE INSULATORS

More specific details of survey results are summarized below

- Almost all of them are temporary faults (distribution) extremely rare for permanent faults
- During Rainy, winter, windy season fault issues noticeable more than other seasons
- In general faults due to insulator is less as mostly it's due to tree branches, animals shorting &bird nesting
- Better storage, handling, transportation and installation procedures are required
- Indian Railways is currently using lower CD insulator of 20 mm/kV which is not as per pollution map that demands mostly 31 mm/kV and partly 25 mm/kV.

The benefits in the use of composite insulator is realized as summarized below:

- Main benefit of polymer is in stone pelting locations
- Field people prefer polymer: light weight, ease of handling, installation transportation
- Reduced time up to about 40 % on replacement of existing insulator with polymer compared to replacing with porcelain (Significant with power block)
- Preferred in high pollution zones; cement factory, coastal/industrial regions due to less pollution related flashover failures when composite insulators are used.
- Majority zones of Indian Railways prefer Polymer over porcelain for listed benefits

Inferences from Table 2 are

- Technically polymer does not require cleaning / much lower maintenance and converting existing porcelain to polymer will result in huge financial savings for Indian Railways considering the overall electrified route km and future electrification plans
- Effective cost of the porcelain insulator increases several times (about 4 times) due to very high life cycle costs compared to polymer

Inferences from Table 3 are:

- It can be observed from the test results exhibited that the samples have not deteriorated mechanically, electrically or in material aspects.
- The test values make it very evident there are no aging related issues with respect to silicone rubber insulators.

## V. CONCLUSIONS

Detailed case study of the Indian Railways Traction network across various zones highlighted polymer is preferred over porcelain for numerous qualitative and quantitative benefits well realized over several years of successful operation. Survey mainly highlighted Indian Railways is using lower creepage distance of 20 mm/kV which is not as per pollution map that demands 31 mm/kV. Considering the life cycle costs, use of polymer insulator will result in huge financial savings for Indian Railways for the overall electrified route km and future electrification plans. Numerous tests performed on the in-service composite insulators were very positive strongly demonstrating it as a preferred choice in future.

## VI. ACKNOWLEDGEMENTS

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