«Kum Kaynaklı Hataları Azaltmak İçin Veri Odaklı Kök Neden Anal izi»

«Data-Driven Root Cause Analysis for Reducing Sand-Related Defe cts»

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2.Oturum / 2st Session

Oturum Başkanı / Session Chairman: Veysel Durak (Erkunt Sanayi)

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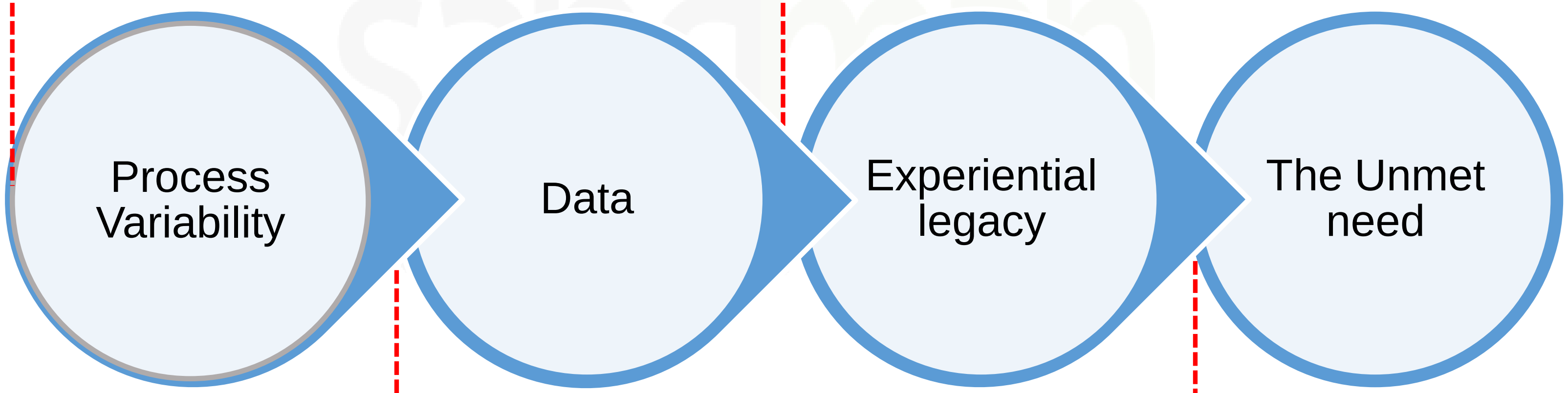
Introduction

- Green sand casting is one of the most economical and widely used technique to manufacture variety of products with different shapes and sizes.
- Casting is a complex process and also known as process of uncertainties.
- The variability in process parameters, return sand, raw materials etc., leads to defective castings.
- In a typical foundry, defects are around 8-10 % of total production in which 50% are due to the green sand.
- Defects are easy to identify and classify, however it is difficult to find the actual root cause of the defects.

The 'Why' of repetitive casting rejections

- Varying product mix
- Varying S/M ratio
- Unmeasured return sand

- Shrinking pool of experts
- Non annotated events



- Available in different pocket
- Uncorrelated with rejection
- Unvalidated

- Predict Causality of rejection
- Reactive to proactive

Cause of repetitive rejections

Solution: Industry 4.0

Root-cause analysis approach

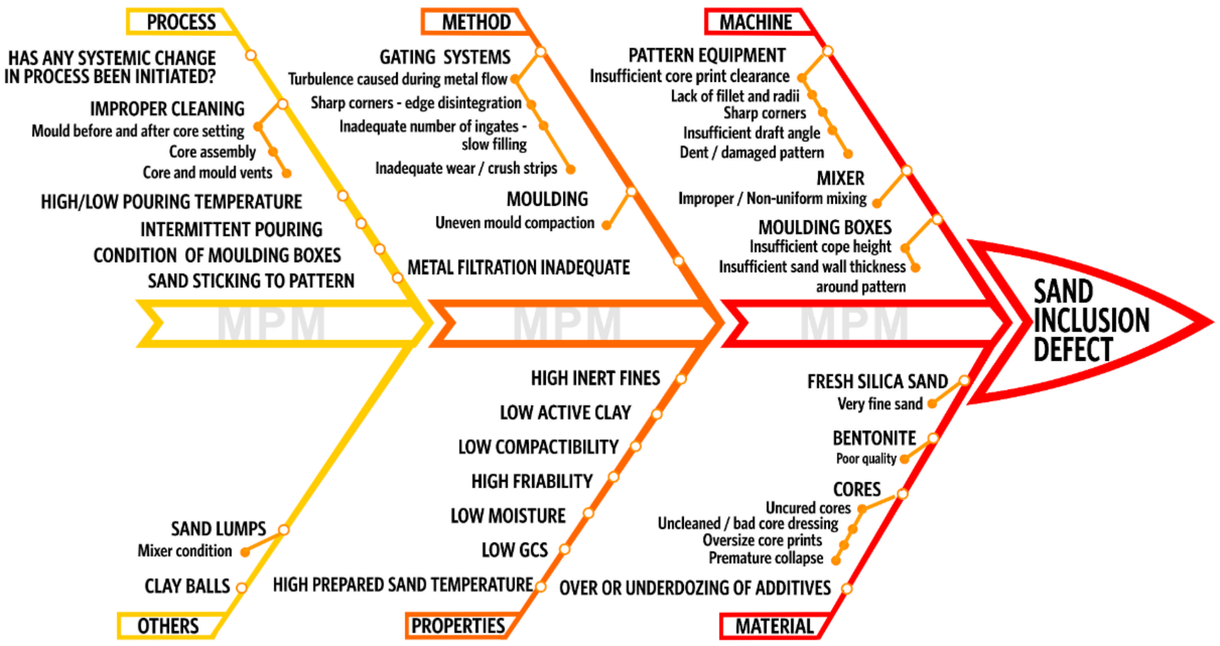
- Root cause analysis is the process of identifying causal factors using a structured approach
- There are multiple methods to execute RCA. Some of the popular methods are:
  - **Five-why-analysis:** It is addressing everything with “why” until it finds the root cause of the event.
  - **Failure mode and effect analysis (FMEA):** It is a proactive approach to root cause analysis based of the legacy/historical data.
  - **Fault tree analysis (FTA):** It constructs a tree structure for the defect as a root and uses Boolean logic to create nodes to figure out cause of defects.
  - **Fishbone diagram (Ishikawa diagram):** It is a pictorial representation of cause-and-effect of a specific event.

Objective

- To analyze the Sand Inclusion defect's root cause using foundry experiential / historical data and data analytics.

Fishbone diagram-A root cause analysis approach

- Fishbone approach of root cause analysis was developed by Dr. Kaoru Ishikawa in 1943.
- The diagram structure is like a fish where the head represents the defect, and the bones represent the possible cause of the defect.
- The fish-bones which represents the cause of defect are classified as process, machine, method, properties, material, and others.
- Recently, MPM-India has designed and developed fishbone charts for six major sand related defects such as blow hole, broken mould, erosion scab, sand fusion, mould swell and sand inclusion. Charts are available on (https://www.mpmindia.com/fishbone)



Fishbone diagram of Sand Inclusion defects
Design and developed by MPM Pvt Ltd India

Data Analysis driven Fishbone diagram

- A Unique data-driven analysis is used in the Fishbone diagram to perform a root cause analysis for six major sand defects.
- Data used are both qualitative and quantitative in nature.
  a) **Quantitative Data:** Sand Inclusion (%), Prepared sand properties.
  b) **Qualitative Data:** Changes in Process, Method, Machine, Others and Materials.
- The change in quantitative data is presented in the properties node and the change in the qualitative data is presented in the nodes namely Process, Method, Machine Material, and Others.

sandman
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Fishbone diagrams for Sand Inclusion Defect

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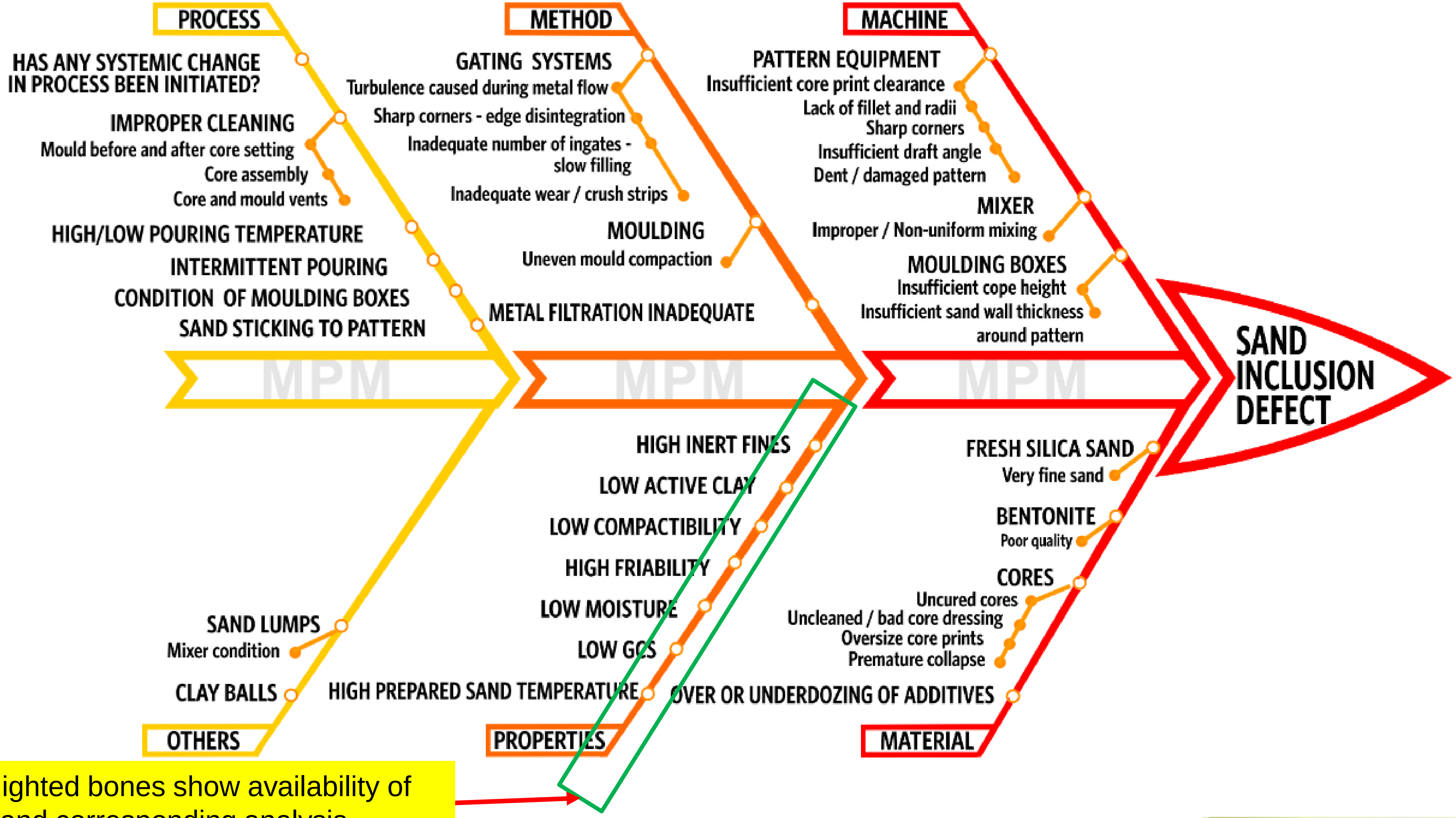

Highlighted bones show availability of data and corresponding analysis

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Workflow of Fishbone analytics for Active nodes

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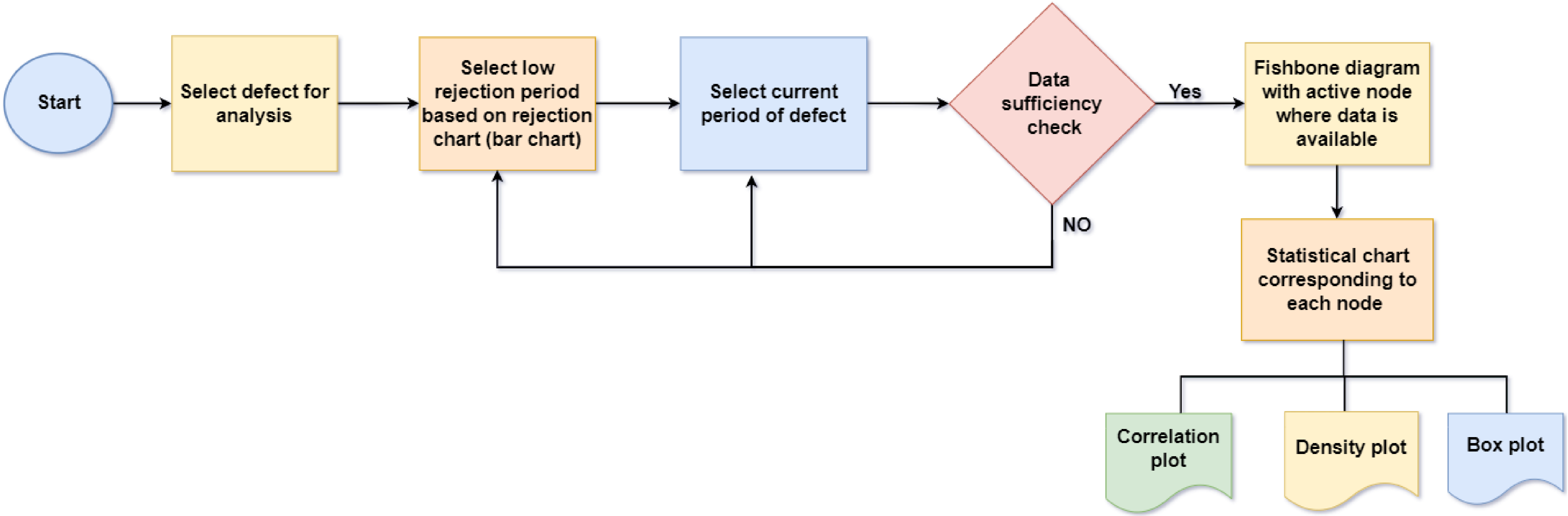


Data information for the present work

- The study has been carried out for a component being manufactured in one of the leading foundry situated in central India.
- The foundry produces ~ 26000 tons castings per year
- The sand to metal ratios of the castings varies from 5 to 9
- The component that has been examined has a total production of around 3700 tons per year and have sand to metal ratio 6.4
- The major defects of this components is sand inclusion

Note: Rejection considered in this analysis in term of rejection %

$$Rejection\,\% = \frac{Rejection\ of\ components}{Total\ production\ of\ the\ components} \times 100$$

Data information for the Present Work

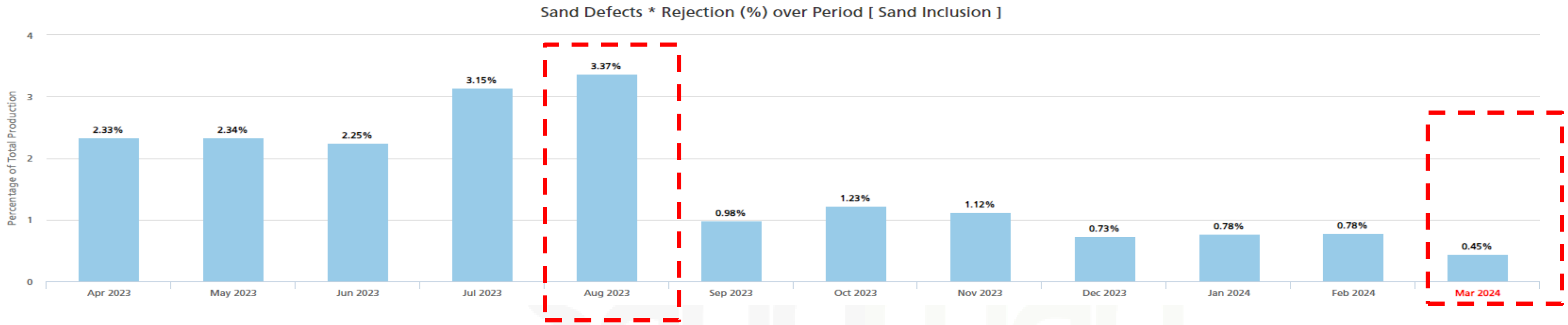
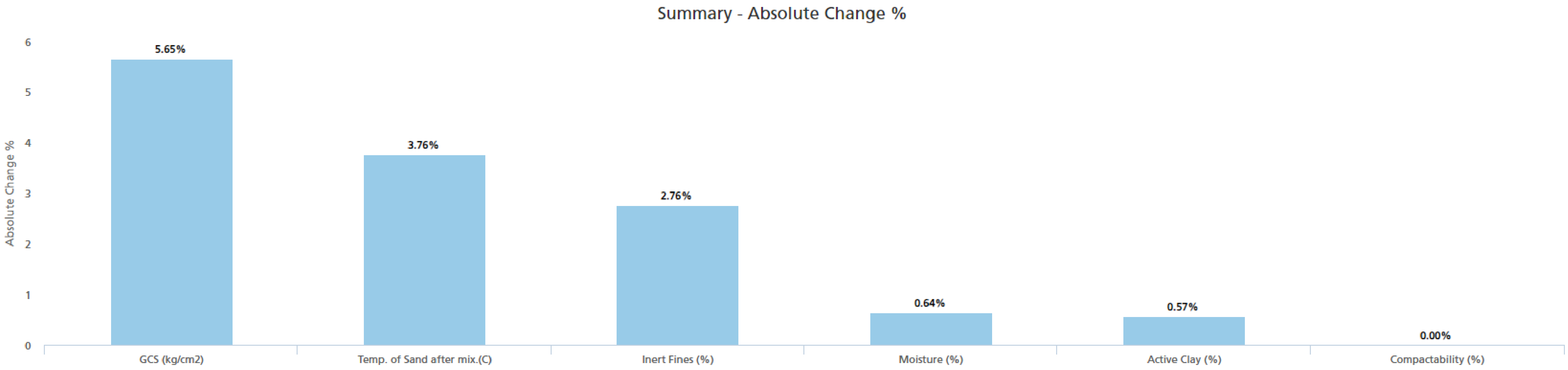


Fig: Rejection trend of component X for the last one Year

- Rejection rate is high in August 2023 and lowest in March 2024
- We considered March-2024 as a reference period and August 2023 as comparison period to understand the reason for high rejection in August 2023
- This analysis also helps us to define the operating range of sand parameters based on lowest rejection period

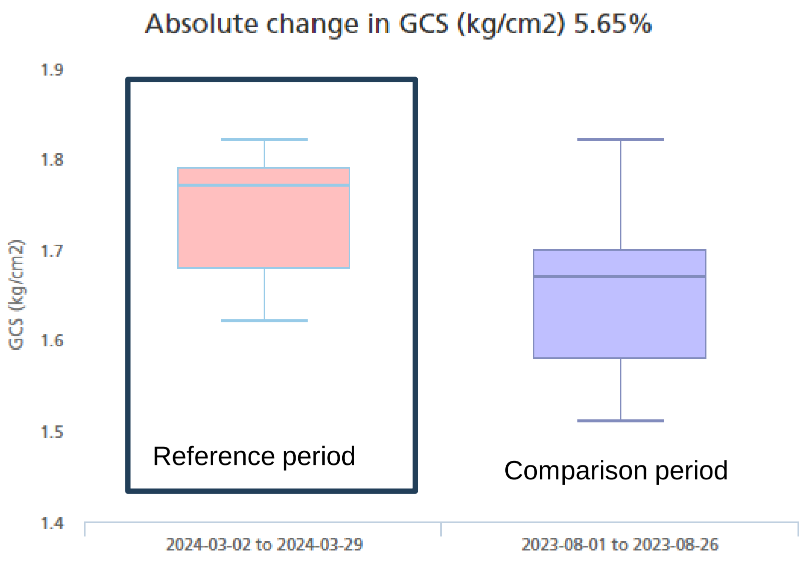
RESULT AND DISCUSSION

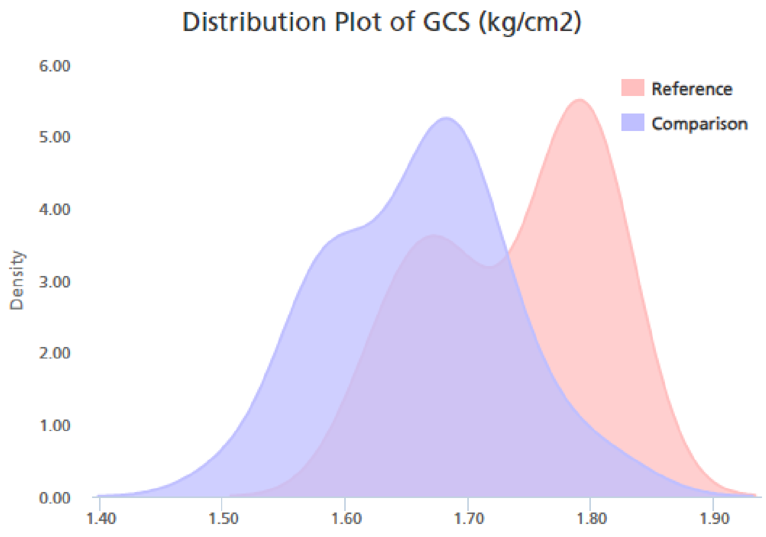


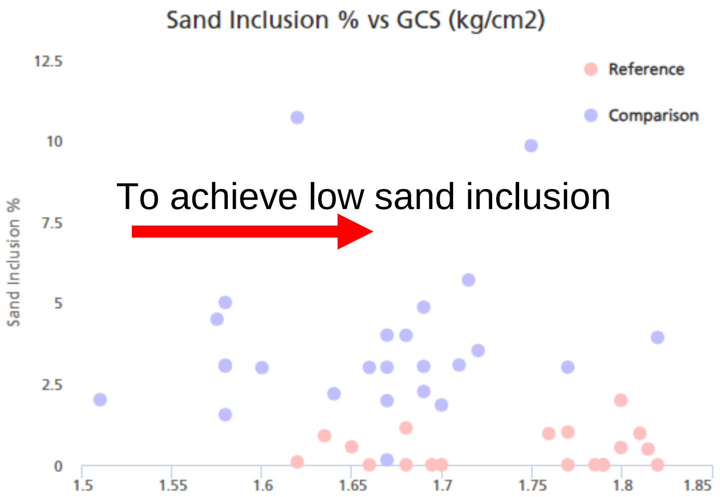
- The absolute change (%) in prepared sand properties between the reference period (low rejection period) and the comparison period (high rejection period) are displayed.
- It is computed by taking the median values for all attributes between the reference and comparison periods.

$$\%Change = \frac{abs\ (Median_{Ref} - Median_{Comp})}{Median_{Ref}}$$

Variation in GCS







- The GCS Values for the Reference period and the Comparison period are displayed.
- The reference period when the sand inclusion was low, the GCS (kg/cm2) values were varying between 1.7 (Q1) to 1.78 (Q3) compared to high rejection period 1.58 (Q1) to 1.69 (kg/cm2) (Q3).
- To maintain lower rejection the operating point for GCS can be considered as 1.7 to 1.78

Note: Q1 and Q3 represent the 1st (25th percentile) and 3rd (75th percentile) quartiles of the sand properties as shown in the box plot.

Variation in temperature of sand after mix

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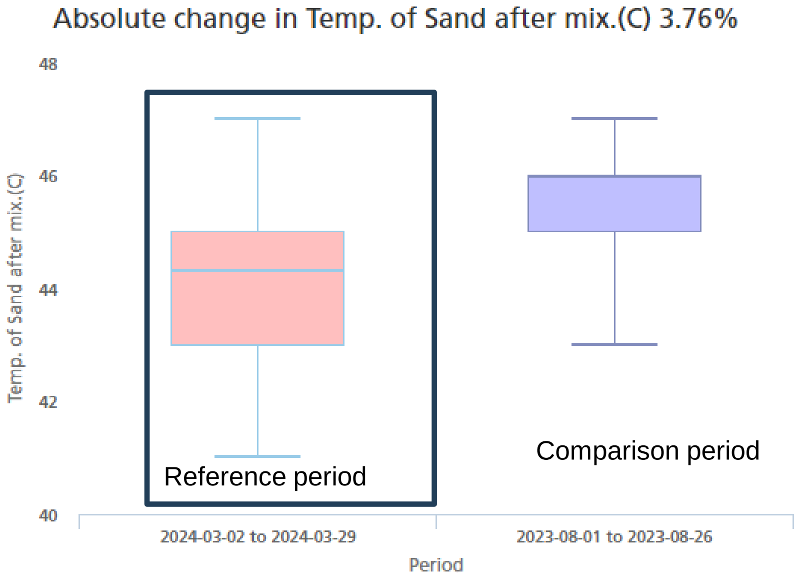

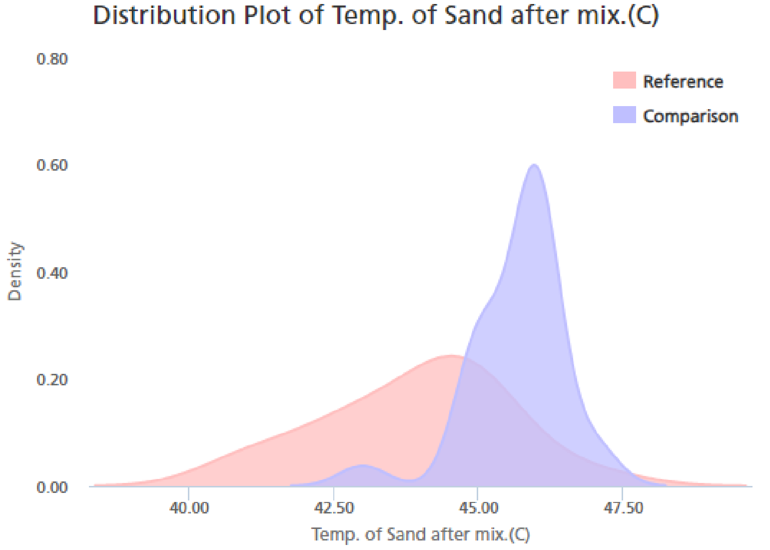

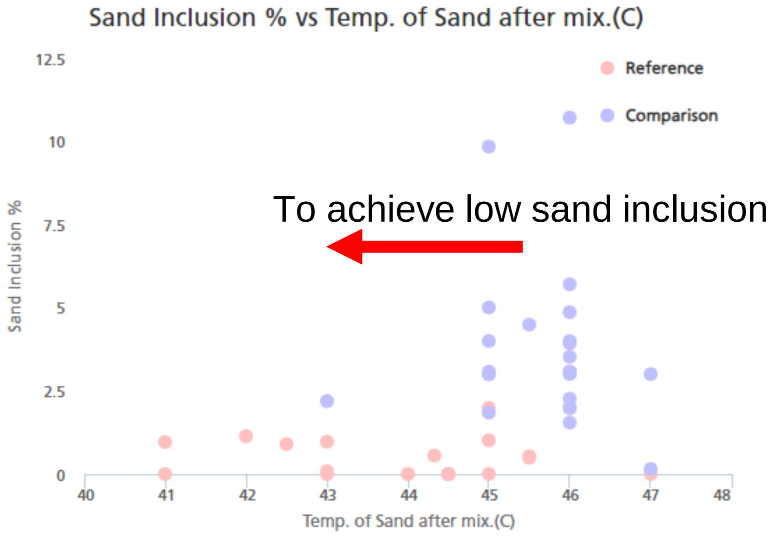

- The Temperature of sand after mix Values for the Reference period and the Comparison period are displayed.
- The reference period when the sand inclusion was low, the Temperature of Sand after mix. (°C) varies from 43 (°C) (Q1) to less than 45 (°C) (Q3).
- The Temperature of sand after mixing should be kept in between 43 to 45 (°C) to achieve low sand inclusion (%).

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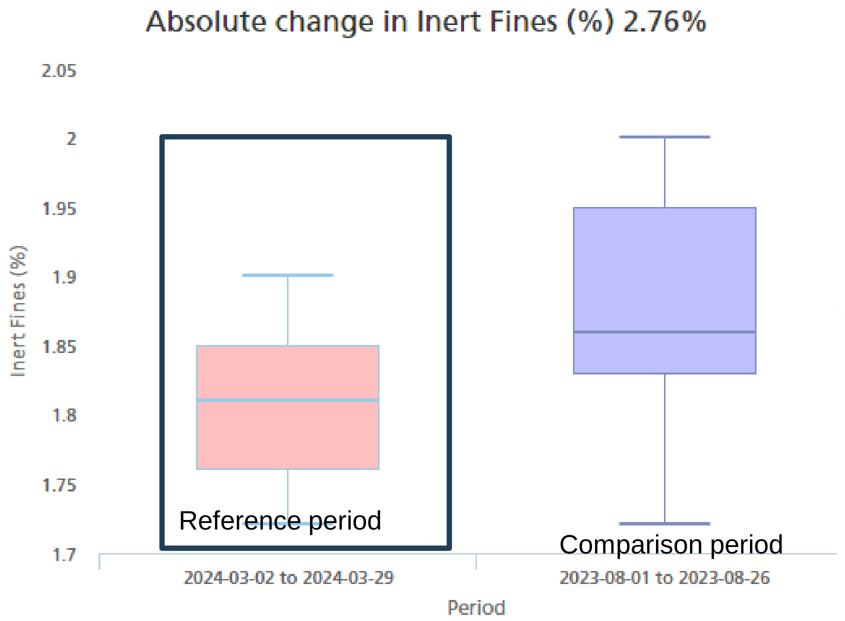
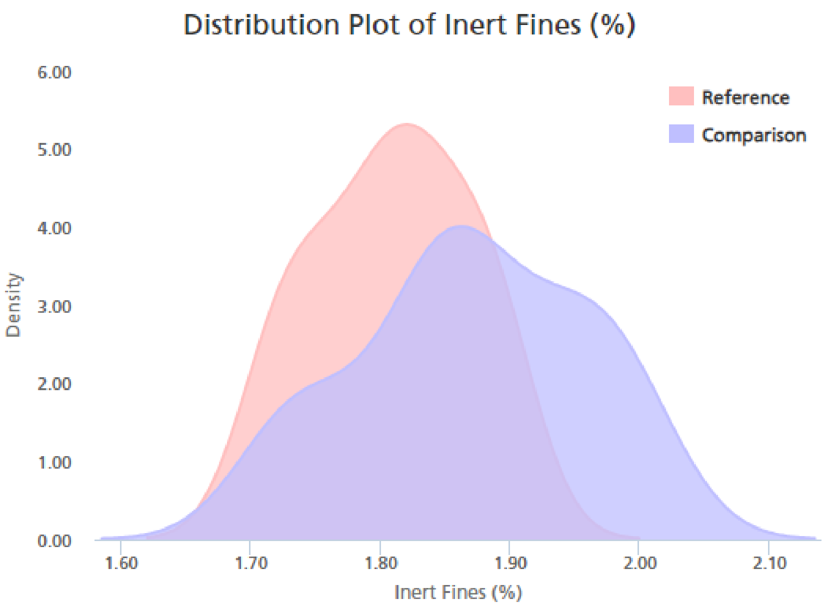
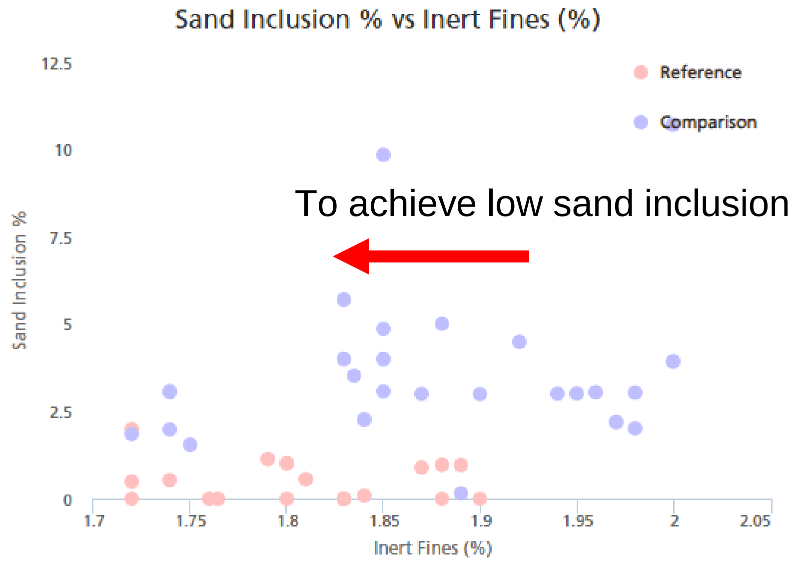
Variation in Inert Fines

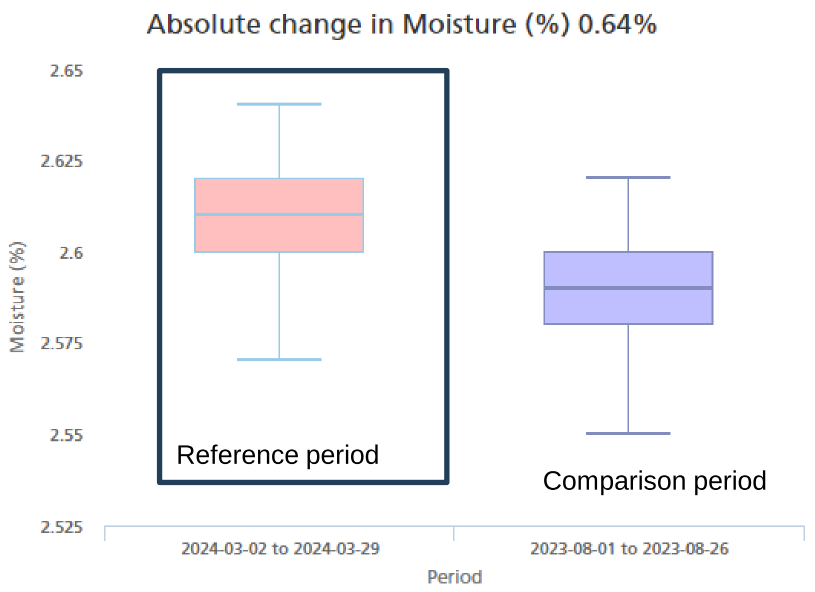


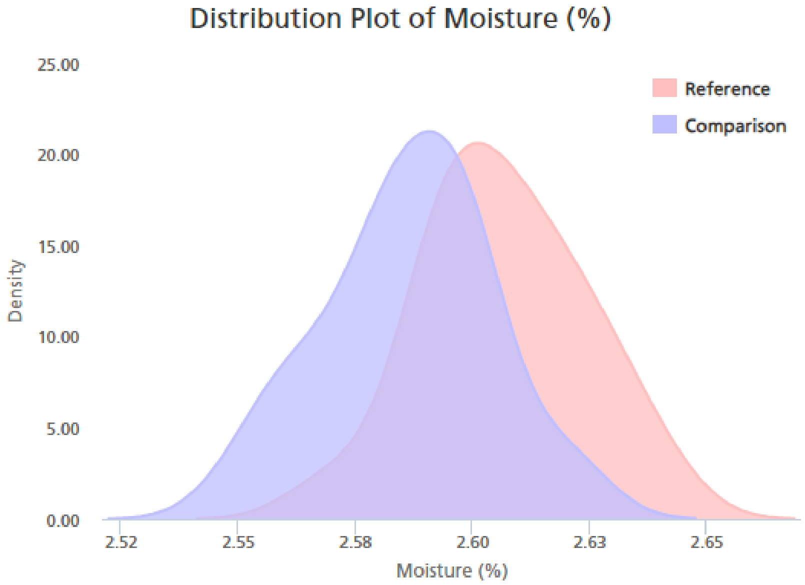


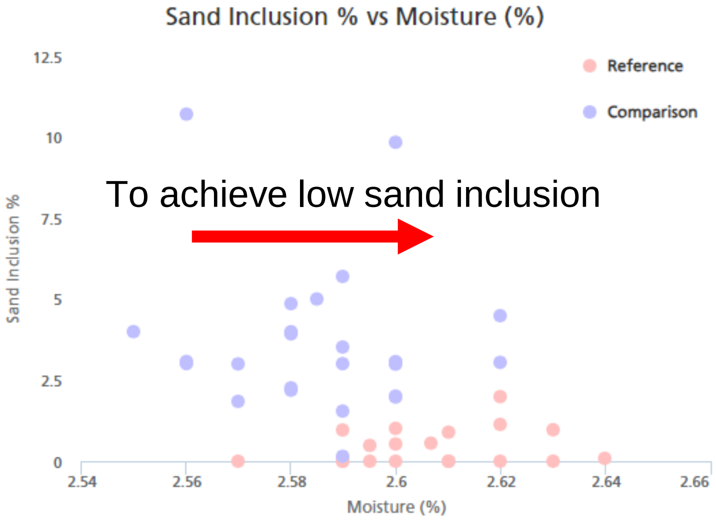


- The variations in Inter Fines (%) between the reference period and the comparison period are displayed.
- The reference period when the sand inclusion was low, the Inert fines (%) were low and ranged from around 1.76 (Q1)to 1.85 % (Q3).
- The Inert Fine (%) should be kept between 1.76 to below 1.85, to maintain the low sand inclusion.

Variation in moisture

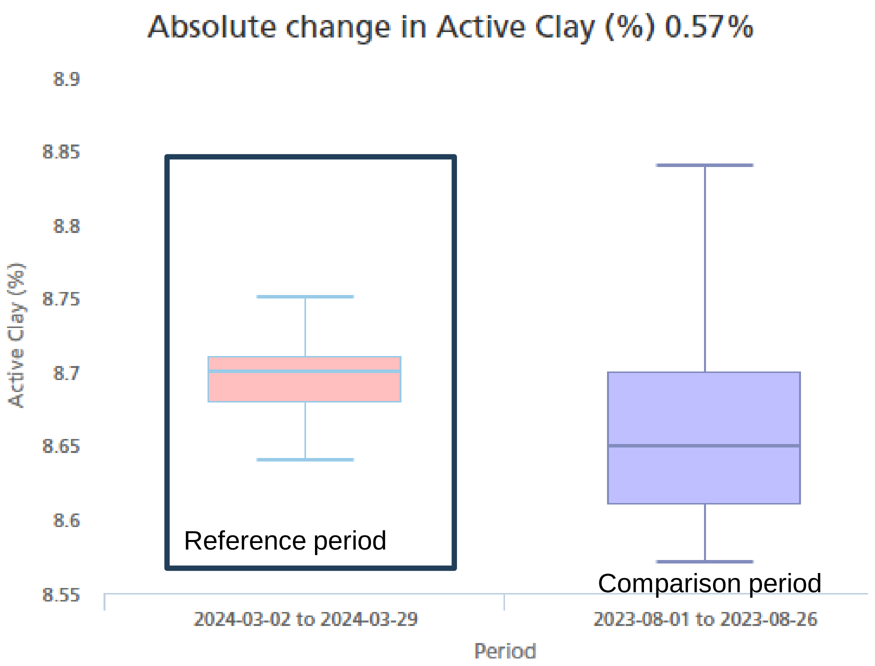


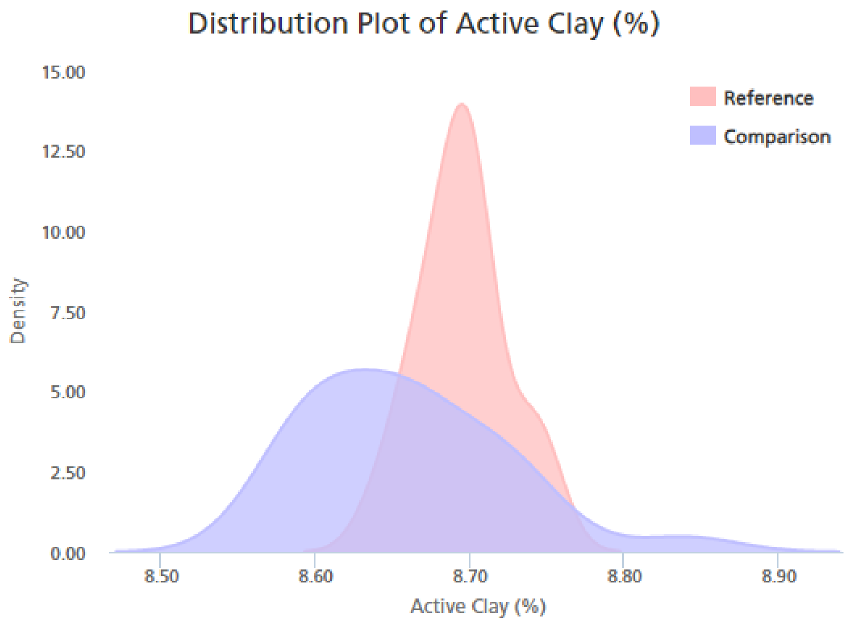


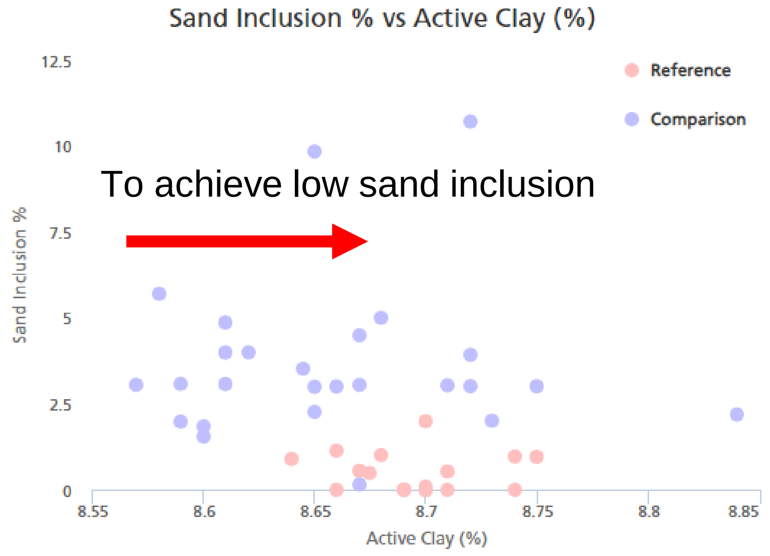


- The variation in Moisture (%) between the reference period and the comparison period are displayed.
- The reference period when the sand inclusion was low, the moisture (%) was in between 2.62 (Q1) a 2.64 (Q3).
- To prevent sand inclusion (%)-related rejection, it is advised to maintain a moisture content of 2.62 to 2.64.

Variation in Active Clay







- The variations between the Active clay (%) between the reference period and the comparison period are displayed.
- The reference period when the sand inclusion was low, the active clay (%) is between 8.66 (Q1) to 8.72 (Q3).
- To keep the sand inclusion low the active clay (%) should be kept between 8.66 to 8.72 (%).

Conclusion

1. **Effectiveness of Fishbone Analytics:** Data analytics-driven fishbone analytics proves to be an efficient tool for root cause analysis, specifically in identifying actionable items to mitigate sand-related defects in the Green Sand Foundry.

2. **Insights from Historical Data:** By analyzing historical data, valuable insights can be drawn by comparing the variations in sand-related properties during periods of high and low rejection rates.

3. **Sand inclusion (%) defect can be reduced** by controlling the properties like GCS (kg/cm^2), the temperature of sand after mix (°C), Inert fines (%), Moisture (%), and Active clay (%).

4. It can be used to derive operating region of the sand parameters to minimize rejections

MPM INFOSOFT Team wishes to thank “TÜDÖKSAD and Distinguished leaders and members of the Foundry Industry” for providing us the invaluable opportunity to present “DATA-DRIVEN ROOT CAUSE ANALYSIS FOR REDUCING SAND-RELATED DEFECTS” at “12th International Foundry Congress”