RIVESTIMENTI IN ANELLI DI CONCI PREFABBRICATI DI GALLERIE REALIZZATE CON TBM

Brescia, 23 Giugno 2022

Aula Magna Ingegneria - Università di Brescia (UniBs)

ORGANIZZATORI

Collegio dei tecnici della Industrializzazione Edilizia

Società Italiana Gallerie
Italian Tunnelling Society

CON IL PATROCINIO DI

Ordine INGEGNERI della provincia di Brescia

UNIVERSITÀ DEGLI STUDI DI BRESCIA 1982 | 2022

fib CEB-FIP Fédération Internationale du Béton

MEDIA PARTNER

ingenio informazione tecnica e progettuale

SAIE Bologna, 19/22 ottobre 2022

PRESENTAZIONE

Ghella 1894 5 Generations of Tunnelers

Alessandra Tana
Ghella
Precast Manager
atana@ghella.com

Controllo qualità, danni, mitigazione, riparazione e rinforzo: punto di vista del costruttore

MISSION *Build excellence in a sustainable and innovative way*

VISION *Leave a better world to the next generations*

Founded in 1894, ***Ghella*** is a leading Company in the construction of major infrastructure projects worldwide.

With its ***unique skills*** and ***experience in underground works***, Ghella is involved in the construction of many infrastructure projects such as subways, railways, motorways and major roads, significant water and hydraulic works.

The Company has most of its workload in the international markets, mainly in ***Oceania***, ***Far East***, ***Latin America*** and ***Europe***. The Company has a presence on a global scale with a workforce of ***over 3,600 people***.

With the use of ***modern technologies***, continuous training program for the workforce, development of ***innovative productive methods*** combined with the highest attention to ***safety*** and ***environmental requirements***, Ghella has completed complex engineering works that have contributed to the Company's dynamic and steady growth as well as the social and economic development of the territories in which it operates.

Along with its presence in major infrastructure works, Ghella is involved in the ***renewable energies sector***, with the development, construction and operation of renewable sources production plants, mainly photovoltaic and hydroelectric, in Italy, Central America and the Middle East.

Tradition & Innovations for Over 100 Years

Domenico — **Adolfo** — **Giovanni** — **Giandomenico & Enrico** — **Federico & Lorenzo**

- **1867** — *The beginning as a small sub-contractor in Egypt and Turkey*
- **1894** — *Founding of the Company; first time in Australia*
- **1898** — *Russia, Trans-Siberian railway tunnels*
- **1905-14** — *China, Vietnam and Beacon Hill tunnel in Hong Kong*
- **1924-50** — *Focus on Italy*
- **1950-60** — *North America*
- **1970-95** — *Central America and Venezuela*
- **2003** — *Europe (France and Greece)*
- **2008** — *Brazil and Argentina*
- **2010** — *Australia*
- **2015** — *Vietnam and Norway*
- **2016** — *UAE*
- **2018** — *New Zealand*
- **2020** — *Canada*

Our Way

We operate at the highest standards of ***integrity*** at all levels of our organization.

Safety is vital to us: no deadline is more crucial than having our people return safely home every day.

We strive to guarantee ***Health & Wellbeing*** of our people and of the ***communities*** that benefit from the infrastructure we build.

We endeavor to integrate our projects in the ***local ecosystems*** and to participate actively in the global efforts to mitigate ***climate change***.

Our ***commitment*** in these areas is expressed in our ***sustainability strategy***, as we strive to promote continuous improvement and foster innovation to build a better world.

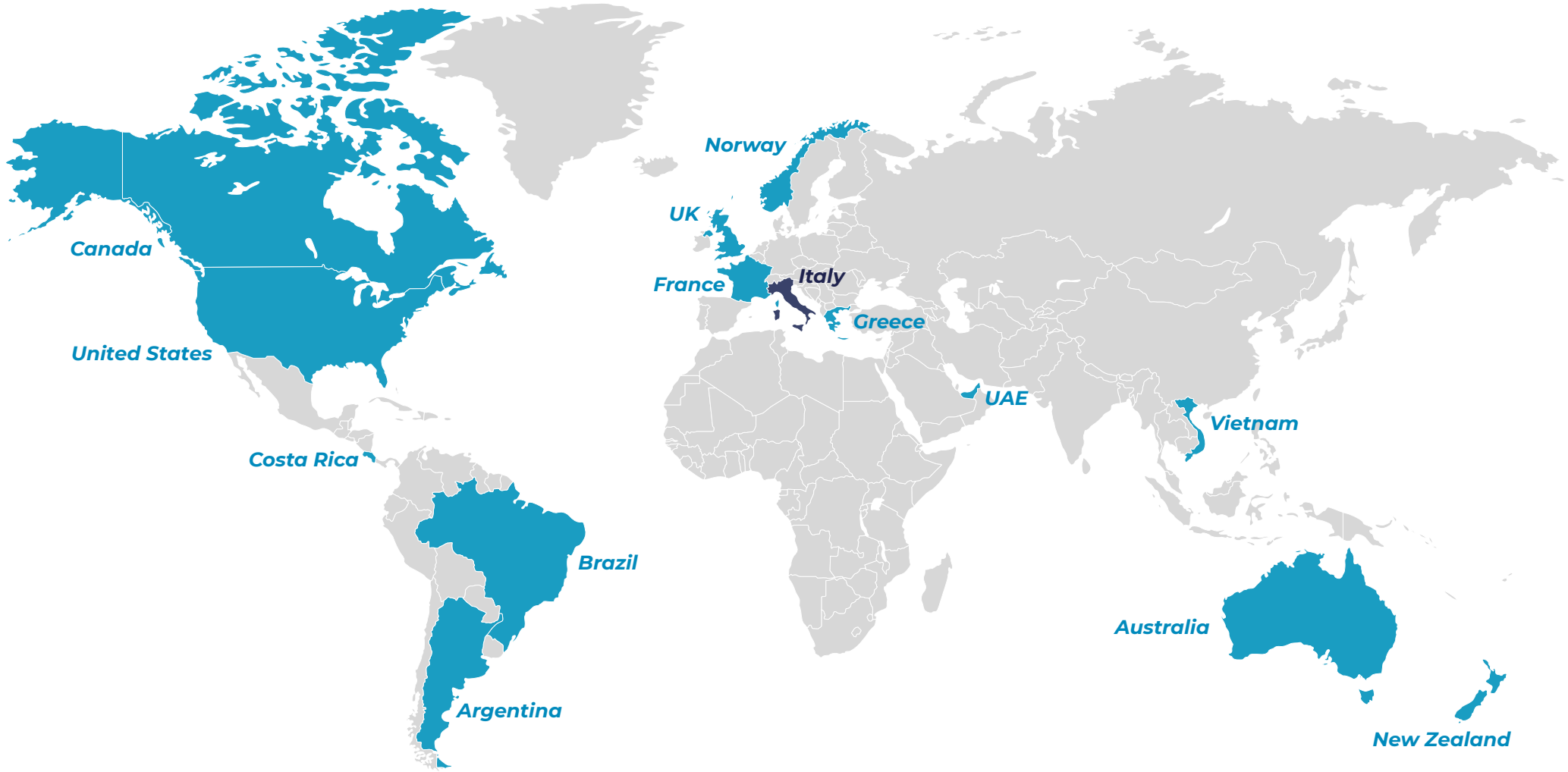
We contribute to local economic growth by creating ***value & opportunities*** through the high ***quality & innovation*** of our projects and by ***transfering skills & technical expertise*** to local workers.

Ghella Worldwide

14 Countries

24 Languages

+3.600 Employees



Core Business

ELSE

MERLE

HIWA-I-TE-RANGI

KATHLEEN

MABEL

WENDY

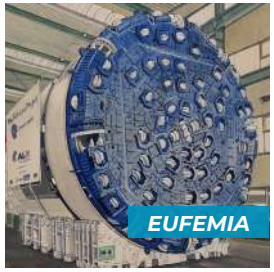
MUM SHIRL

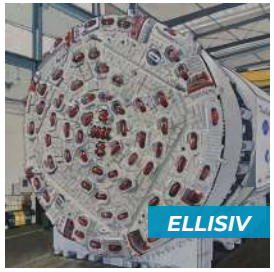
NANCY

VIRGINIA

FLAVIA

SERENA


EUFEMIA


ELLISIV

ANNA

MAGDA

VALENTINA

ELISA

FEDERICA

IPPODAMO

SOFIA

ANNABEL

JOYCE

ARGENTINA

WALKIRIA

PAOLA

ANITA

CATERINA

BETANIA

Production

240km
WITH TBM

230km
WITH CONVENTIONAL METHODS

13km
WITH PIPE JACKING

ROADS & HIGHWAYS

16 HIGHWAYS

+300km OF ROADS

RAILWAYS & SUBWAYS

+35 RAILWAY LINES

+16 SUBWAYS

PHOTOVOLTAIC

1.125 MV IN OPERATION

WATER

+24 HYDRAULIC WORKS

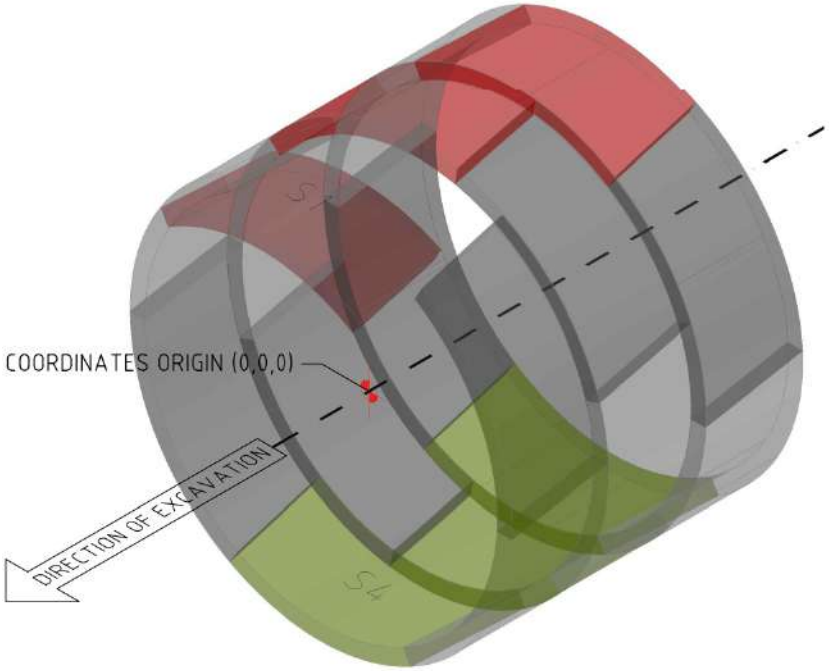
+11 HYDROELECTRIC WORKS

Segments: *Quality control, damages, mitigations & reinforced*

Quality Control

Damages detection

Mitigation measures



Final scope

Segment life cycle

Phase 1 → Segment Production

In row materials

Reinforcement Ass

Mould Preparation

Casting

Demoulding

Repair

Storage

Shipping

Phase 2 → Segment Transport & delivery on site

Transport to site

Worksite Storage

Transport to TBM

Phase 3 → Segment Installation

Installation

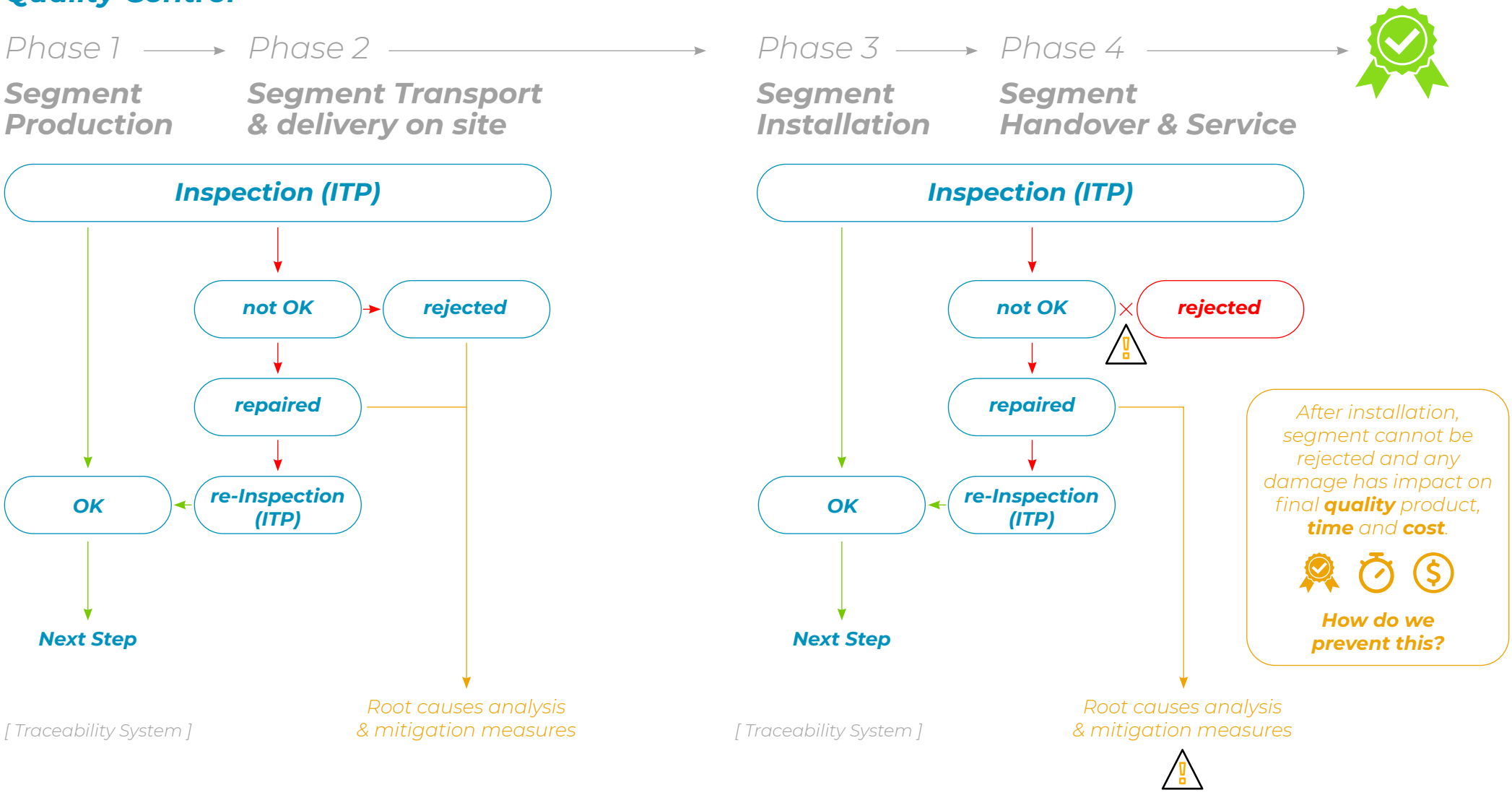
Phase 4 → Segment Handover & Service

Handover & Service

SCOPE: *delivery of a product compliant with quality and durability requirements*

Segment quality acceptance process

Quality Control



Hot point: *correct damages detection & recording*

1. 2. 3. 4. 5. 6.

DATA RECORDING

1 ID	2 Damage position						3 Damage class								4 Damage Timing					5 Damage Detection		6 Repair & Acceptance			
Damage ID	TBM no.	Ring no.	Ring Position	Ring Type	Segment no.	Segment O'clock position	Damage Type	Damage Classification (Classification of segment damage according to ITA Working Group 2)	Tolerances (can be adjusted according to the specific requirements of the project)	Width (mm)	Length (mm)	Water Tightness	Notes	Picture Link	Time of Damage	Ring Installation Shift	Ring Builder	Shift Engineer	Supervisor	Relevated by	Date	Repairing Date	Repairing Procedure	Repairing Date Acceptance	Status

PHENOMENA OBSERVATION

- *Dashboard of global incidences*
- *Defect along alignment*
- *Data integration*
- *Data integration*

ANALYSIS & ACTIONS

- *Sensibility Analysis*
- *Root Causes Analysis*
- *Analysis and Actions*
- *Lesson Learned*

Classification of segment damages

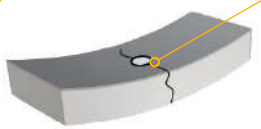
.1

Crack starting from joint in longitudinal direction in-between thrust/dowel/bolt/ packer locations

.2

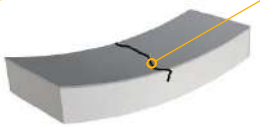
Crack starting from joint in longitudinal direction at thrust ra/ dowel/bolt/ packer locations

.3



Crack starting from joint in longitudinal direction running through grout socket/ shear pin recesses

.4

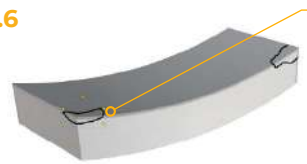


Crack starting from internal face of segment

.5

Crack in circumferential direction

.6

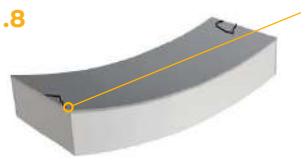


Spalling at segment corner

.7

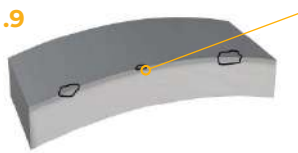
Spalling at segment edges (circumferential joint)

.8



Spalling at segment edges (longitudinal joint)

.9

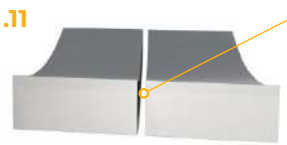


Damage to outer edge of circle joint

.10

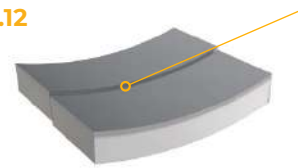
Damage around coupling elements: Shear dowel, bolt and dowel pockets, cam & poket, tongue & groove

.11



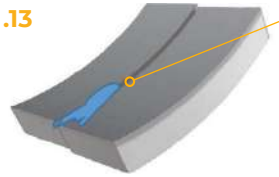
Excessive gap between adjacent segments

.12



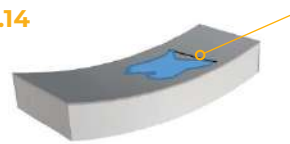
Excessive offset between segments

.13



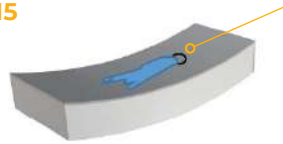
Leakage from joints/ bolt holes

.14



Leakage from cracks

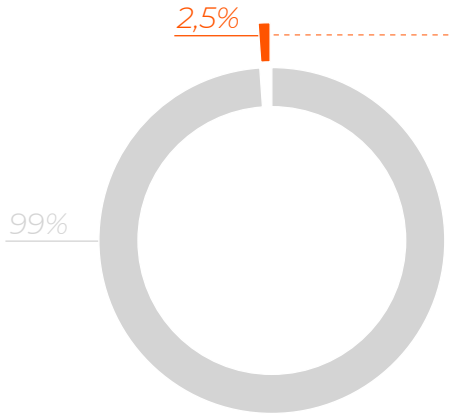
.15



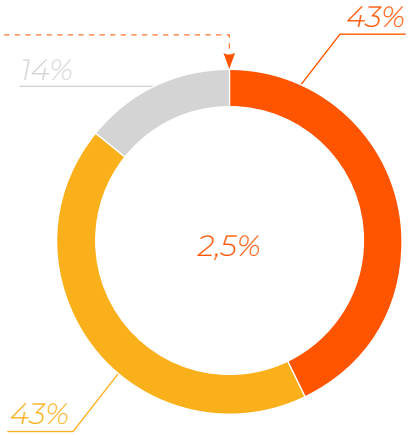
Leakage from insert e.g. grout hole

PCLT damages register output: *dashboard of global incidences*

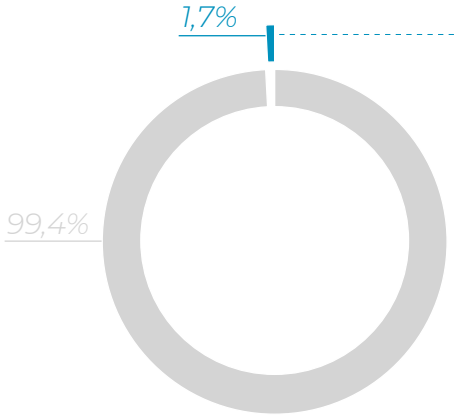
TBM 1
Total Damages
(% on installed segments)



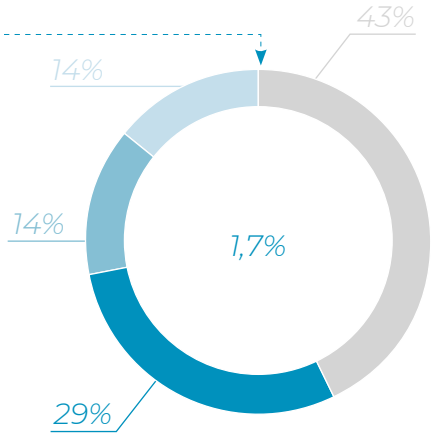
TBM 1
Damages Type
(% on total damages)



TBM 2
Total Leakages
(% on installed segments)



TBM 2
Leakage Type
(% on installed segments)



- *Segments Without Damages*
- *Total Damages*

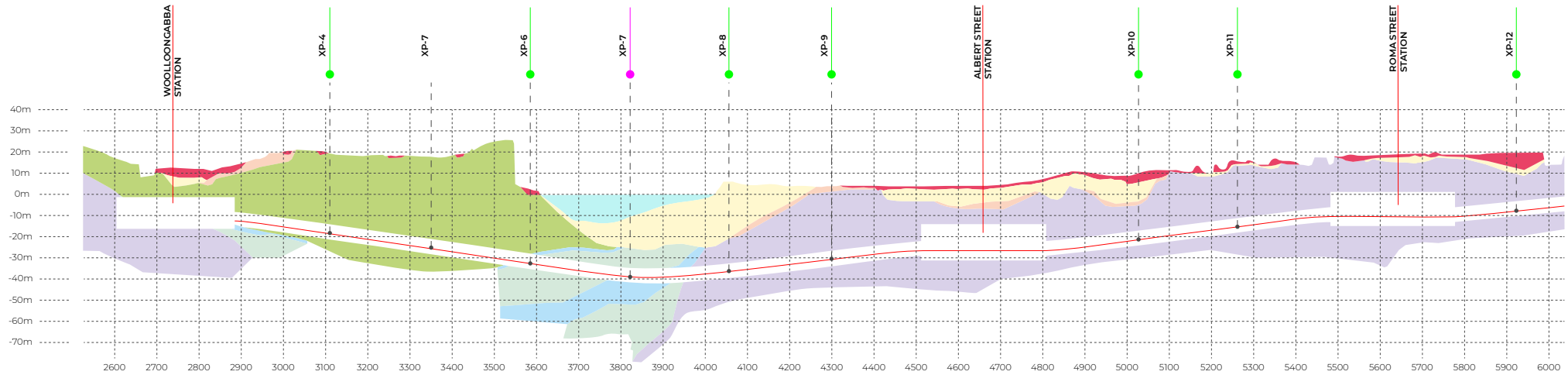
- *Crack*
- *Spalling*
- *Damage to outer edge*
- *Step / Lip*
- *Gap*
- *Leakage without visible damage*

- *Segments Without Leakages*
- *Total Leakages*

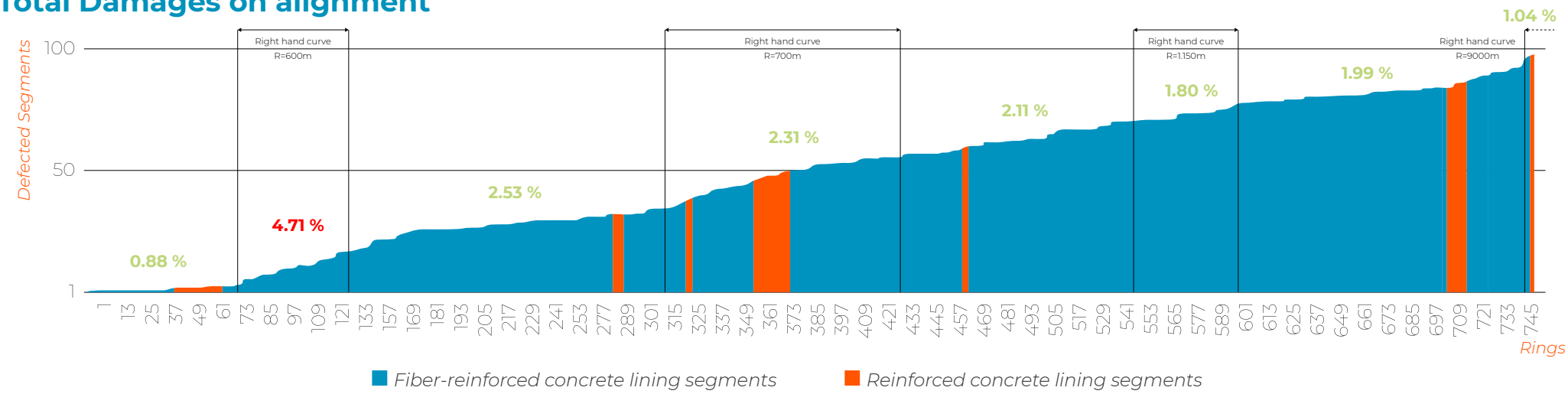
- *Dry*
- *Running water*
- *Drip*
- *Wet*

Important ***to detect the weight*** *of the* ***occurring phenomena***

PCLT damages register output: *Defect along alignment*



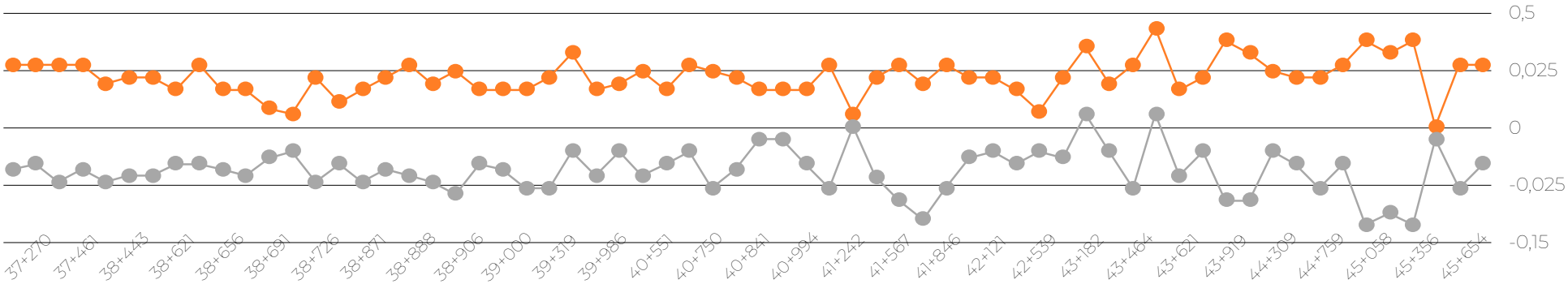
Total Damages on alignment



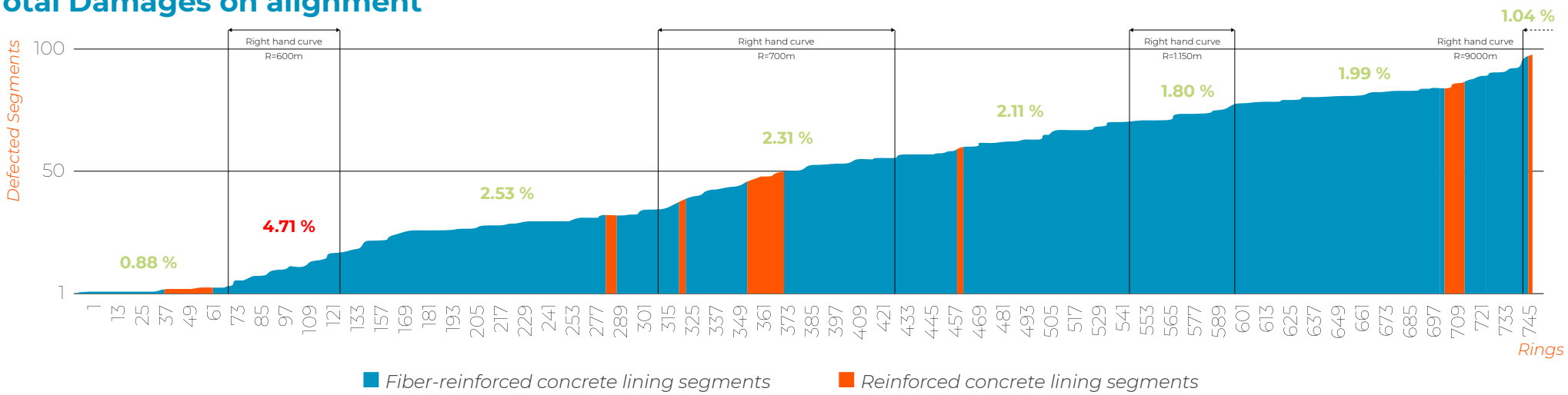
*Important **to detect the weight** of the **occurring phenomena***

PCLT damages register output: *Data integration*

Ring Deformation (M)

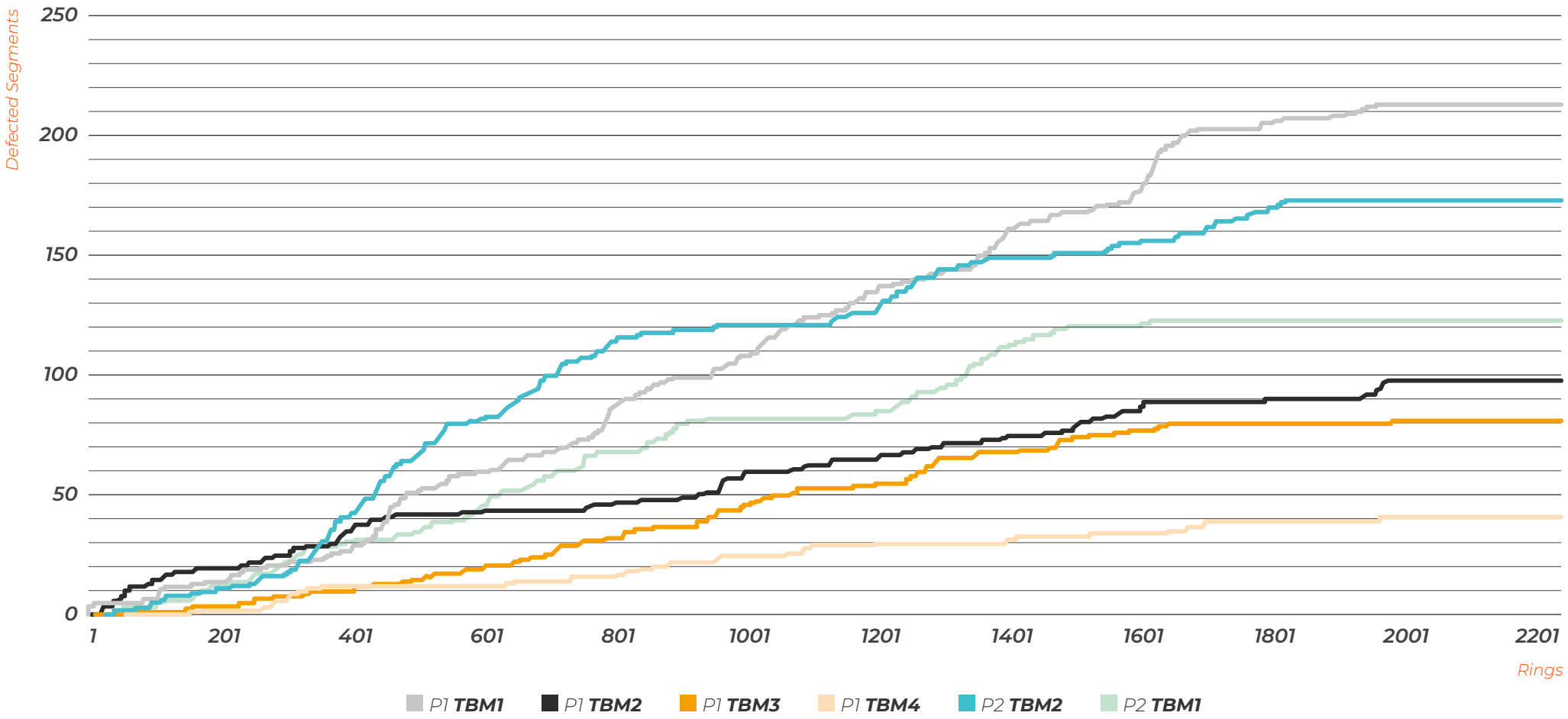


Total Damages on alignment



Important to detect relationship with data coming from other sources: ***Monitoring*** *(Ring ovalization),* ***TBM Parameters*** *(TBM thrust),* ***Specific Survey*** *(Backfilling filling)*

PCLT damages register output: *Data integration*



Important to set side by side different projects with comparable characteristics

Defect traceability software: *Data transfer flow*

Production Site

TBM Site

Precast management system integrated with traceability software at TBM site

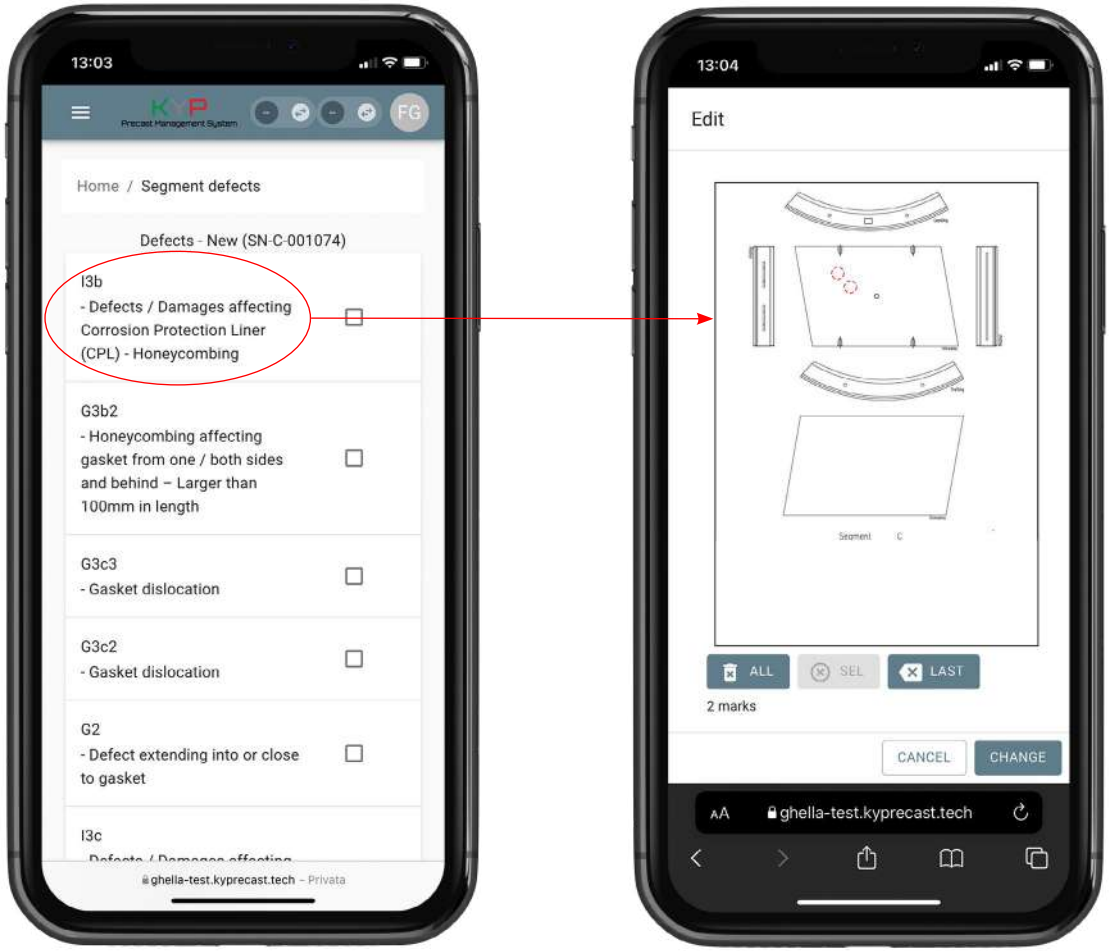
Segment Acceptance

Segment data automatically transfered

Segments/Ring management through barcode scanners

Dashboard

Defect traceability software: *Segment acceptance*



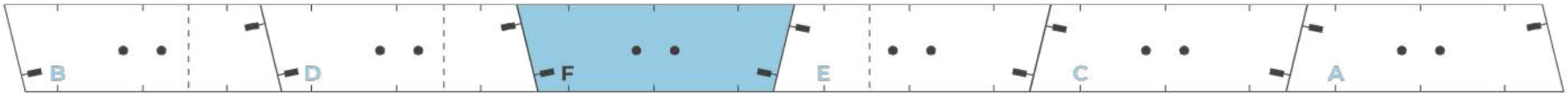
Example** of **defect traceability** software **segment acceptance

Defect traceability software: *Ring installation*

Ring Number 602 (u18)

LOCK

NEW STORE IN POINT



Notes*

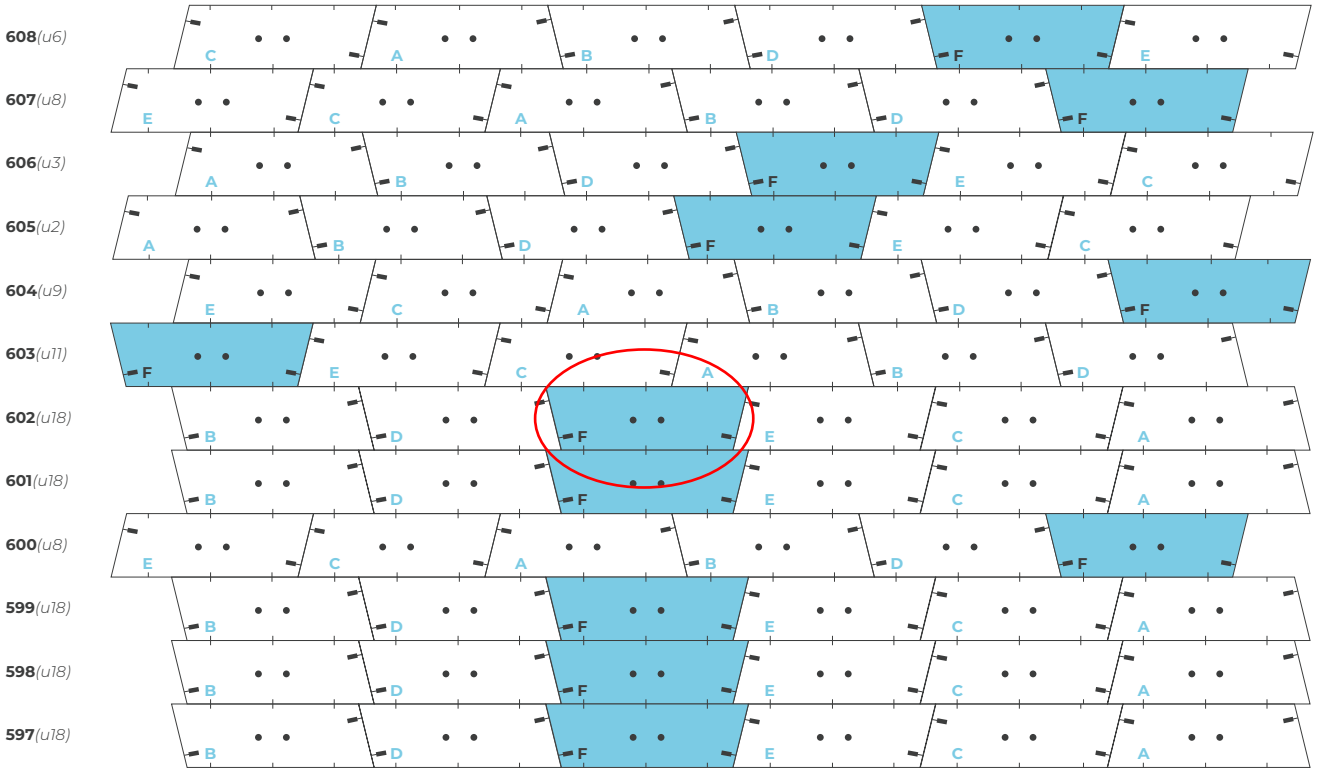
SAVE

	Add defect	Segment	Type	#	Delivery Date	Age	Arrival Time	Locked
6		SN-A-000006	A-1	602	3/05/2021, 15:07:03	93	5/08/2021, 11:58:49	☐
5		SN-A-000001	B-1	602	3/05/2021, 15:07:03	93	5/08/2021, 11:58:34	☐
4		SN-A-000002	C-1	602	3/05/2021, 15:07:03	93	5/08/2021, 11:58:19	☐
3		SN-A-000003	D-1	602	3/05/2021, 15:07:03	93	5/08/2021, 11:58:01	☐
2		SN-A-000004	E-1	602	3/05/2021, 15:07:03	93	5/08/2021, 11:58:44	☐
1		SN-A-000005	F-1	602	3/05/2021, 15:07:03	93	5/08/2021, 11:58:15	☐

CANCEL

Example** of **defect traceability** software **ring installation

Defect traceability software: *Ring key position*



Ring number

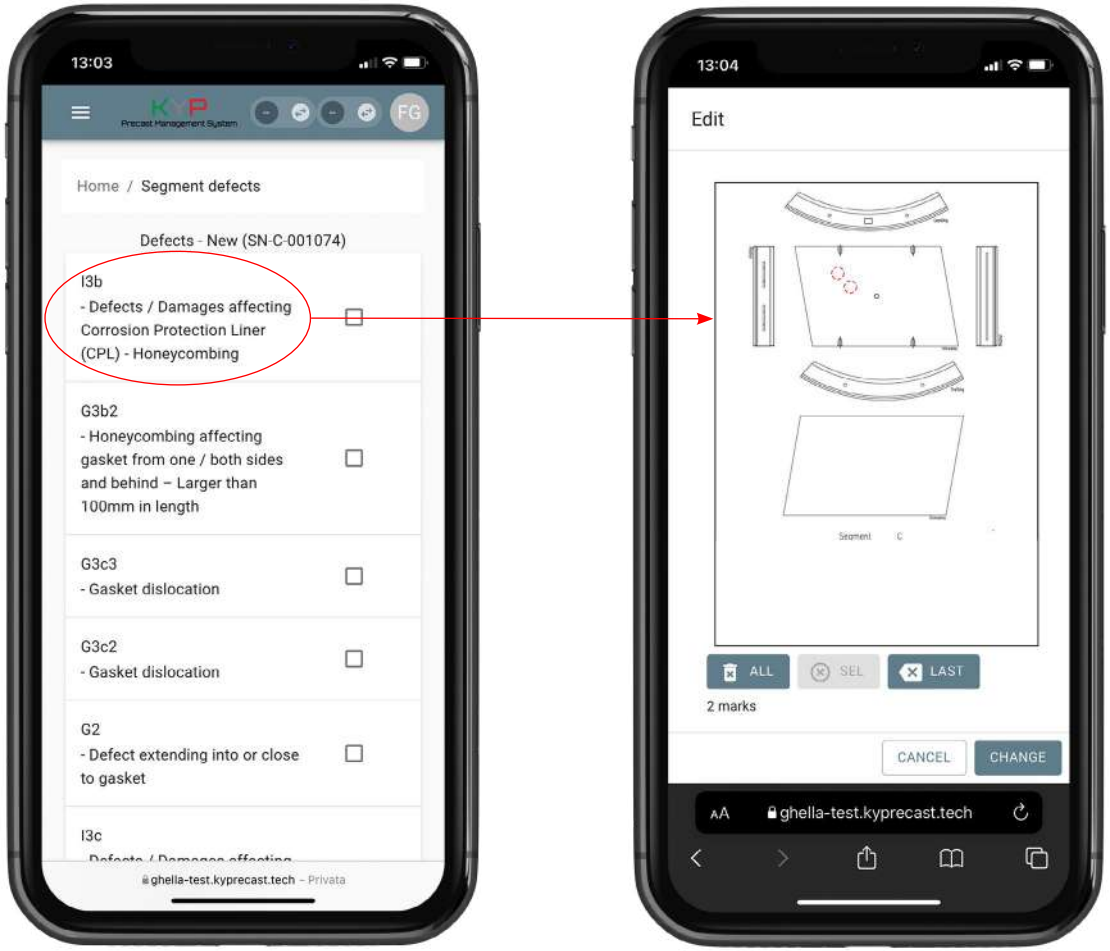
602

REFRESH

FIT TO VIEW

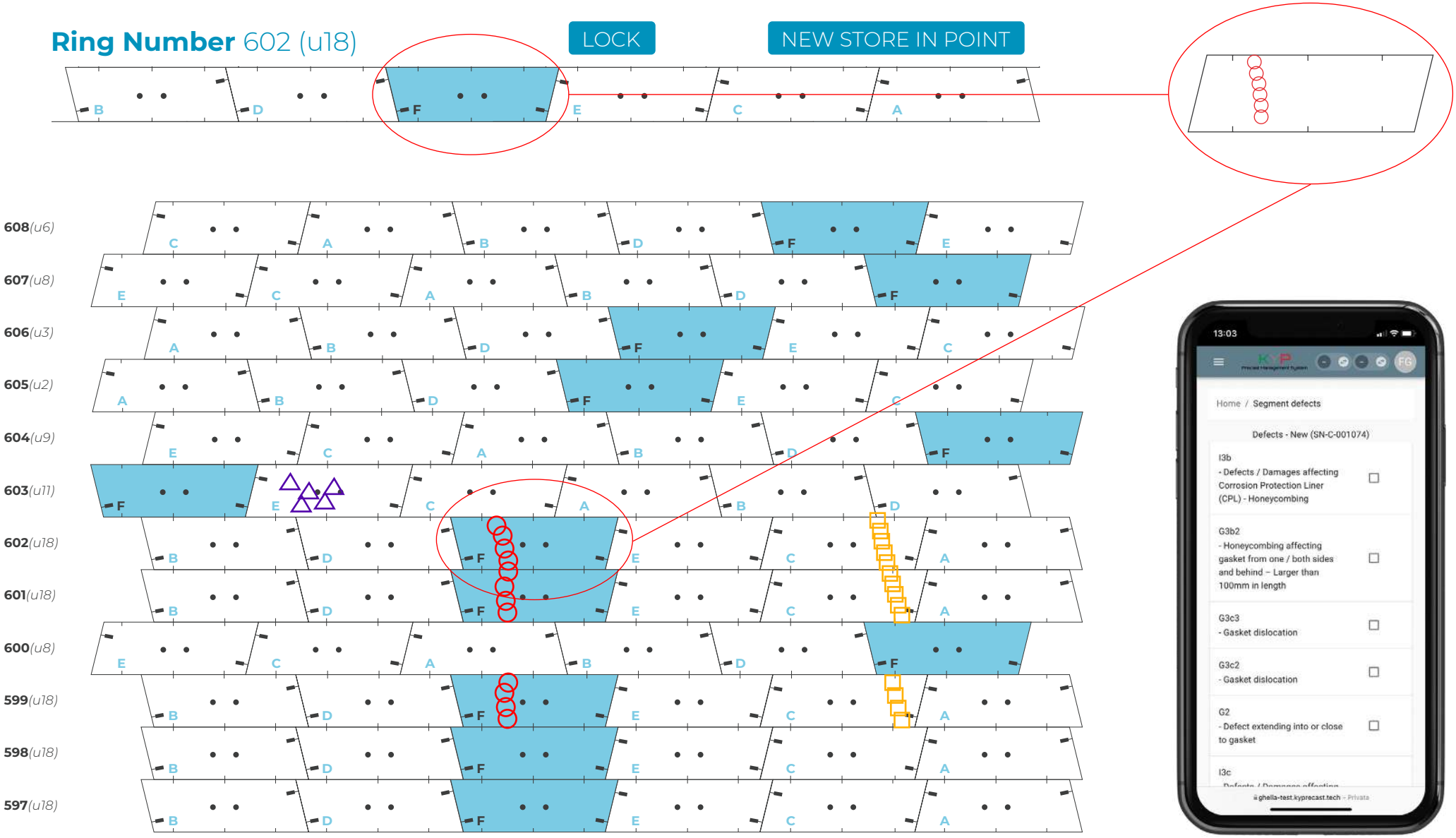
Example** of **defect traceability** software **ring key position

Defect traceability software: *Installed segment control*

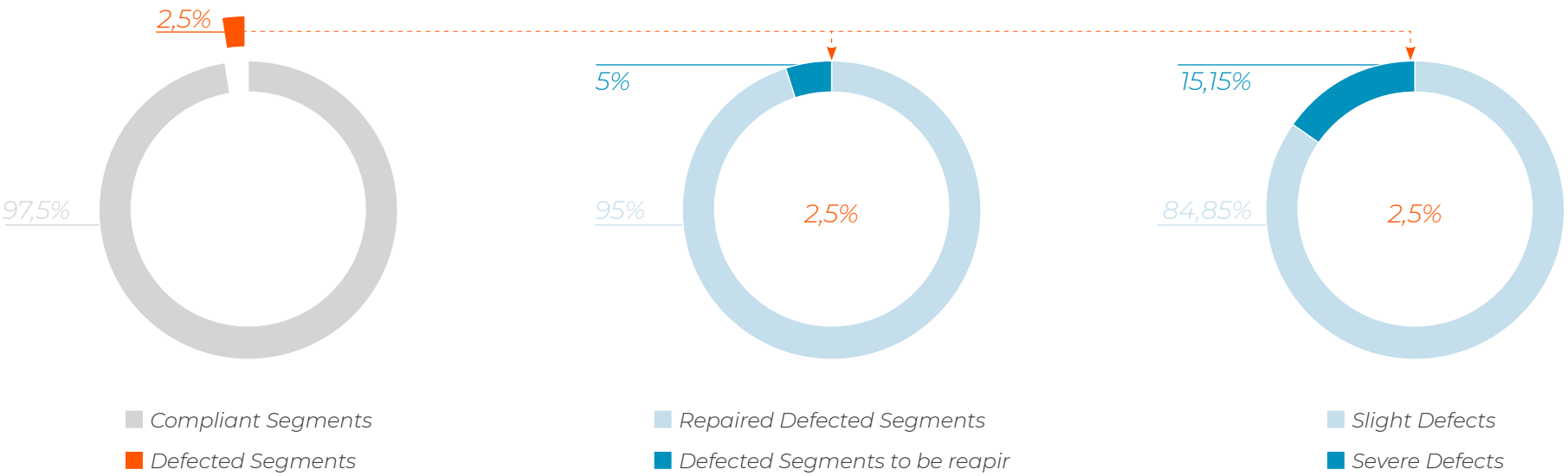


Example** of **defect traceability** software **installed segment control

Defect traceability software: *Defect final layout*



Defect traceability software: *Dashboard 1*



Total installed segments
2400

Compliant segments
2340

Defected segments
60

Total defected segments
60

Repaired defected segments
57

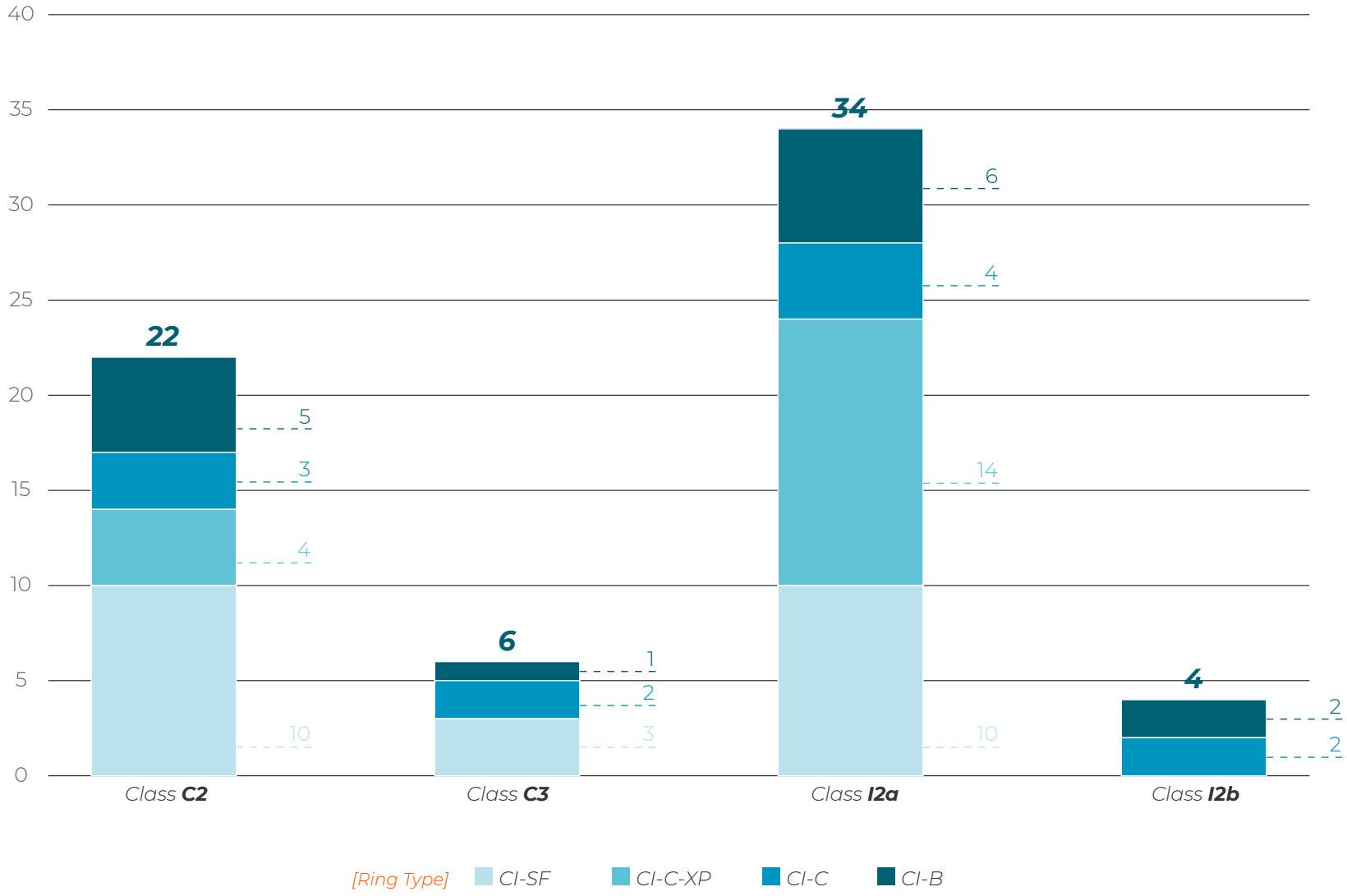
Defected segments to be repair
3

Slight defects
60

Severe defects
10

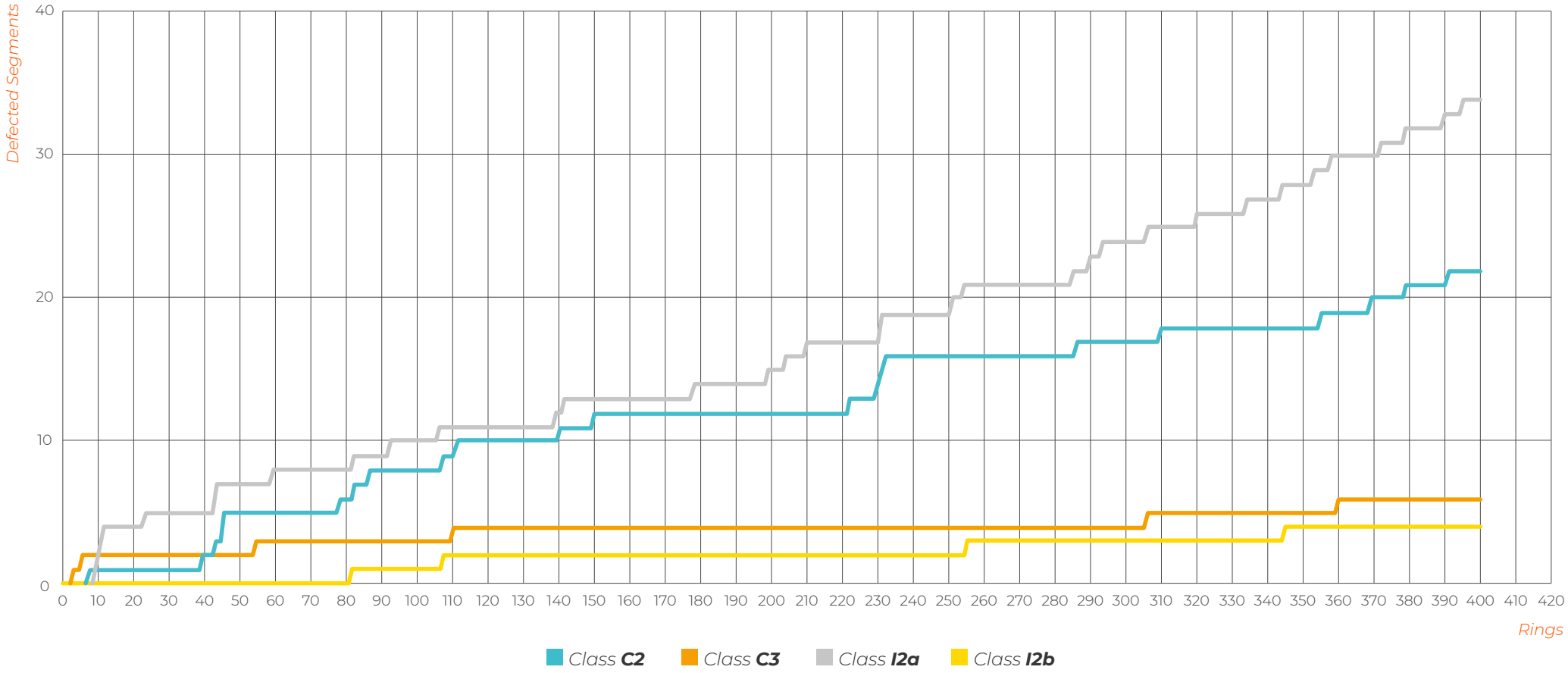
Example** of **defect traceability** software **defect type impact

Defect traceability software: *Dashboard 2*



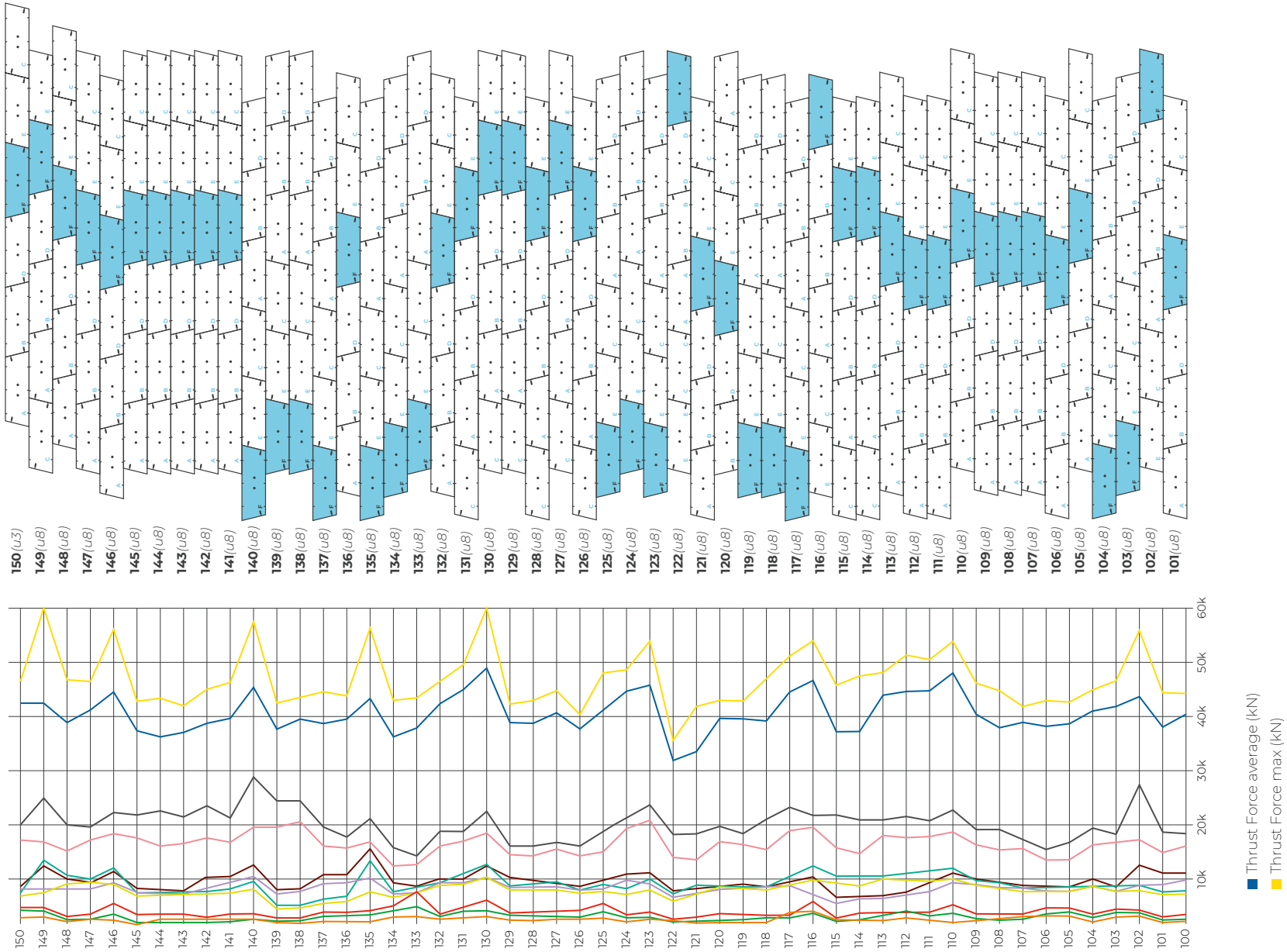
Example** of **defect traceability** software **defect type impact on rings type

Defect traceability software: *Defect on alignment*



Example** of **defect traceability** software **defect type distribution along alignment

Defect traceability software: *Data integration*



***Example** of **defect traceability** software **data integration with TBM parameters** (TBM Thrust)*

Root causes analysis

Datas from
PCTL REGISTER

Defect Type 1
0,9%

Defect Type 2
0,6%

Defect Type 3
0,05%

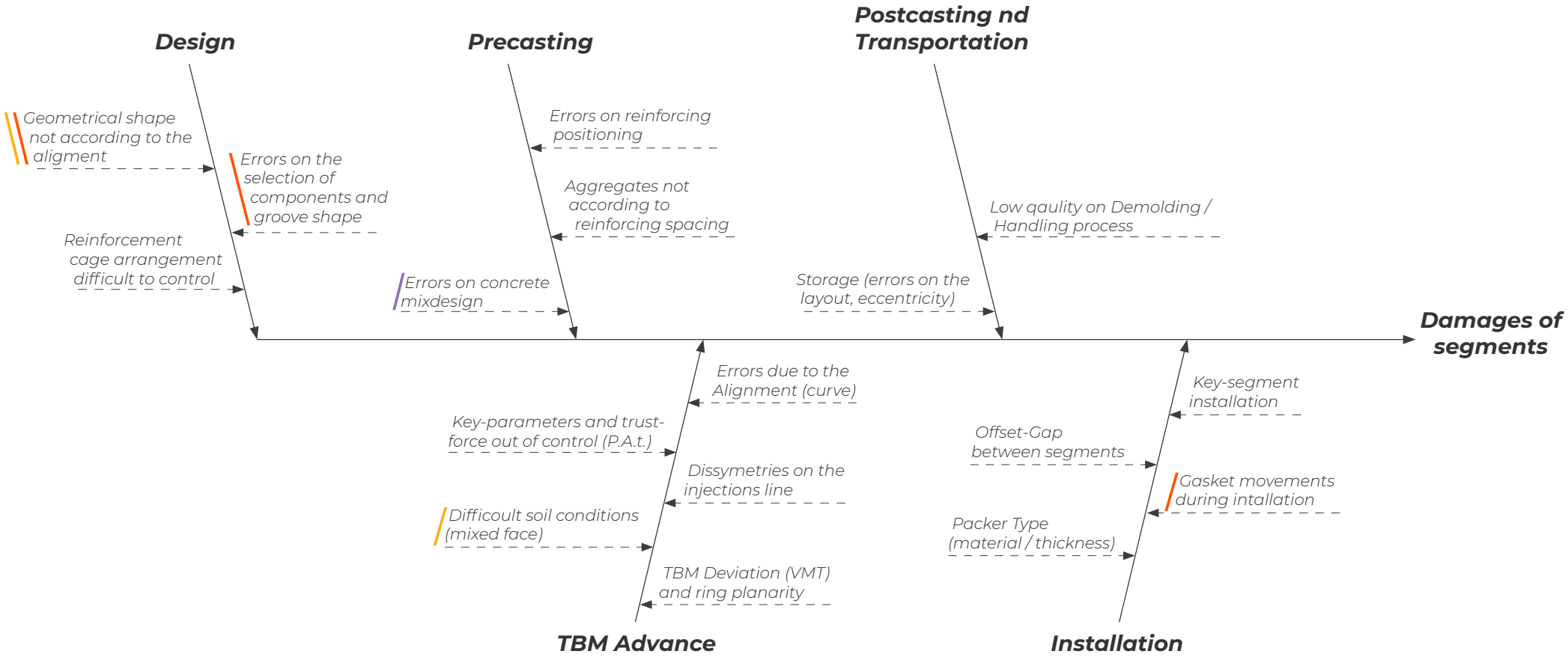
*Identification of prevailing **defect type** in frequency and severity*

Root causes analysis

Defect Type 1
0,9%

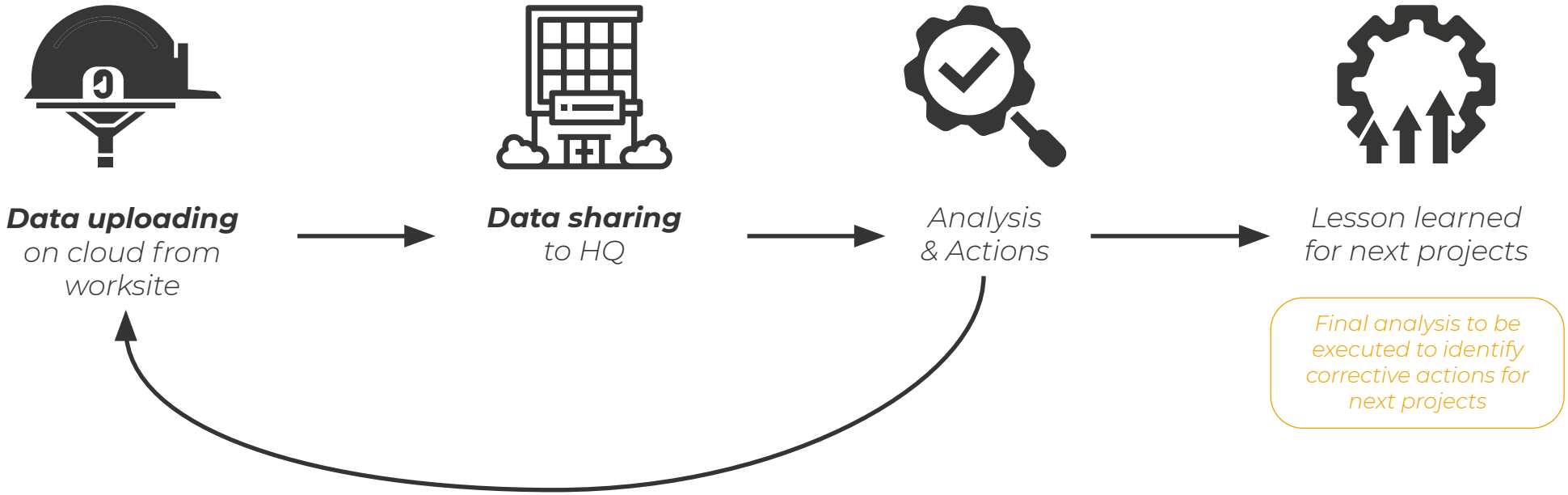
Defect Type 2
0,6%

Defect Type 3
0,05%



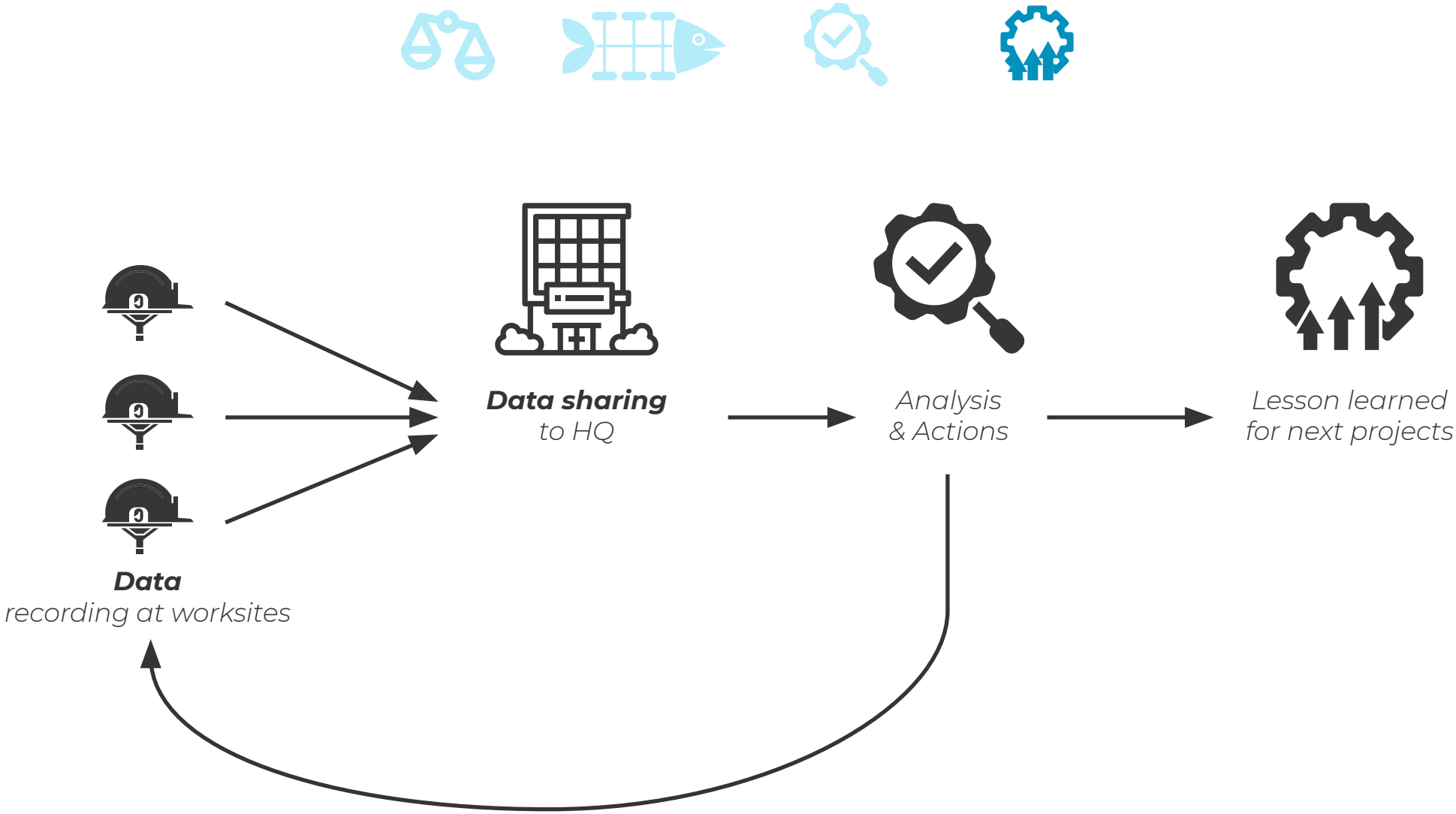
Root causes analysis per each **defect type**

Root causes analysis: *Periodical & iterative*



Periodical analysis to be executed regularly in order to identify corrective actions in real time

Root causes analysis: *Transversal*



Transversal analysis among projects to be executed to identify corrective actions in both on going or future projets

Mitigation measures: *Example of recurring damage*

Transversal data analysis allowed to detect both specific and recurring damages

Damage ***Type 1*** — ***Specific***

Damage ***Type 2*** — ***Specific***

Damage ***Type 3***

Example of recurring damage

Spalling at corner due to gasket compression load with loss in watertightness

Damage ***Type 4*** — ***Specific***

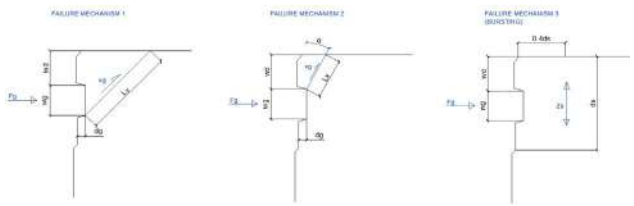
Damage ***Type 5*** — ***Specific***

Mitigation measures: *Spalling at corner*

Already implemented mitigation measures

.1 Gasket selection according watertightness requirements with reduced stiffness and soft corners

.2 Analytic verifications of failure mechanism



.3 Analytic verifications of failure mechanism at T-Joint

BUT →

Difficulty in simulating with analytical method the transfer of the deflection loads in the corners for anchored gasket.

The protrusion of rubber in the corners that occurs frequently during construction of the rings is not taken into account in the testing and characterisation procedures.

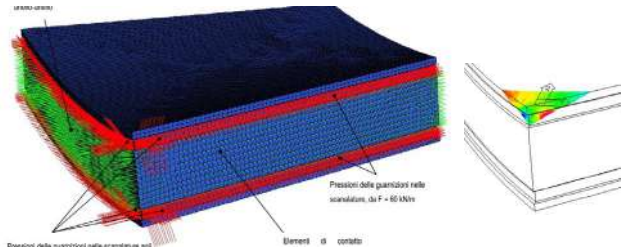
Furthermore, whether the application of gaskets on acute angles (<90°) implies an increase in the deflection load, higher than the load determined in the T-joint test for right angles (90°), is not dealt with in applicable recommendations or in testing procedures and it has not been investigated in the industry.

Important ***to implement additional*** *mitigation measures* ***to prevent the occurance of the fenomenon***

Additional on-study mitigation measures

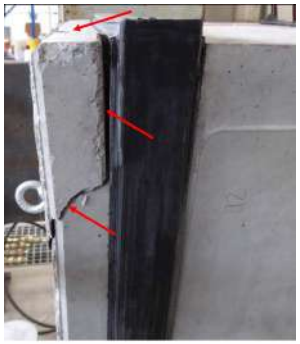
.4 Insights on analytical check at T-Joit creating a worktable between construction company, designers and suppliers to identify a guideline for analytic method

.5 3D finite element model verifications at T-Joint



.6 Reduced scale spalling test according to STUVA recommendations 2019 (for different offsets)

.7 Large scale spalling test



Conclusions

With this presentation we have the pleasure of showcasing the work we are carrying out in Ghella in regards to the correct and detailed cataloguing and recording of segment damages. Some of these reports have already been implemented on our projects, others will be in the future and they are all a fundamental tool to analyze and understand the causes of the damages and consequent actions to undertake on ongoing and future projects.

The standardization of a data collection process and the centralization of information ensure that the know-how acquired from the experience in a specific project can be used in other projects and represents the basis for continuous improvement.

Wherever there is
a future to build