ROBSON HANDLING TECHNOLOGY

MHEA Conference 2014

A Practical Approach to Biomass Handling Systems

Kevin Mannion
Managing Director

Winners at the Sheffield Business Awards

Sheffield Chamber of Commerce & Industry Outstanding Business of the Year Award
The Wake Smith Excellence in Manufacturing Award
Irwin Mitchell Excellence in Customer Service Award

Introduction

In 2012 George Robson were awarded the contract to design, manufacture, install and commission the mechanical handling system associated with the Drax ECO-Store Project.

The System

2 Rail unloading systems

Two dual redundant conveyor systems

Screening, Ferrous Removal, Weighing, Sampling

450,000m^3 Storage via 4 Concrete Dome structures

The system is designed to handle 2800Te/hr of woodpellets per hour via 2m wide trough belt conveyors operating at 2.5m/s seconds.

Conversion of three of the six generating units at the power station to burn sustainable biomass in place of coal.

Challenges

Significant design challenges in the fuel handling facility design.

- High Volumes
- Conveyor Speeds,
- High Wear,
- Dust Propagation,
- Pellet Degradation
- ATEX Zone 20-21 Dust

Tender Design

- High level of engineering certainty
- Significant amount of accurate design information
- Significant risk onto the conveyor designer
- Conveyor system layout, loadings and the sizing of equipment
- Value engineered designs

Tender Design

The drive to secure contracts through value engineered designs can often result in significant compromises

- Conveyor Length Reductions
- The Introduction On Non Linear Transfer Points
- Complex Conveyor Geometry And Increased Lengths To Reduce Conveyor Quantities
- Increasing Conveying Inclines
- Compromising Conveyor Junctions Transfer Points
- Increasing Belt Conveyor Speed To Reduce Conveyor Size.
- Increased Height Chute Transfers.
- A Rationalisation Of Redundancy Features.
- Reduced Design Factoring Of Drives, Gearboxes, Bearings Etc
- Spatial Planning For CDM Covering Construction And Maintenance Access.
- Removal Of Secondary Monitoring And Control Equipment

Tender Design

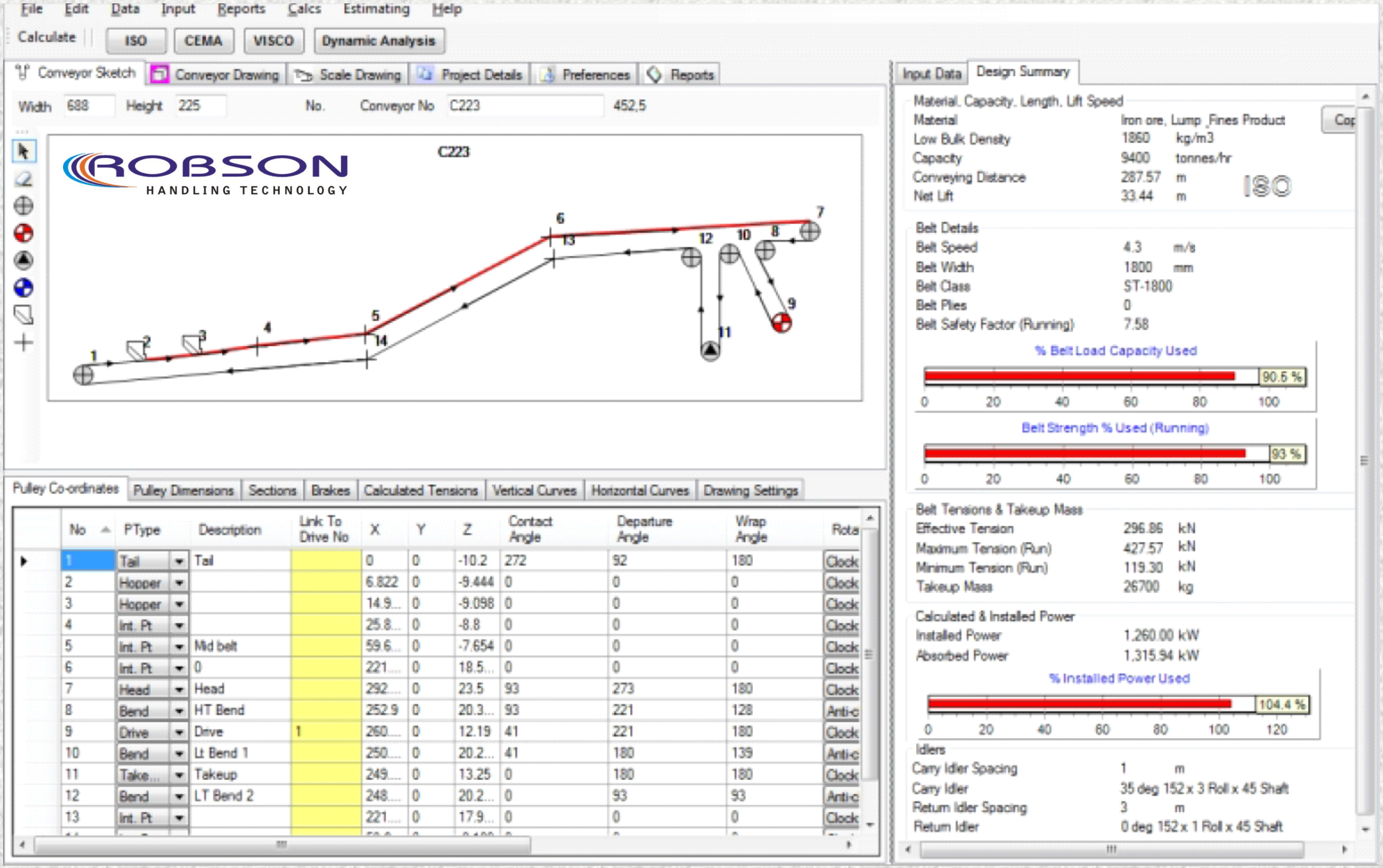

Figure 1 : Summary Report- Dynamic Conveyor Modelling Software.

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Tender Design

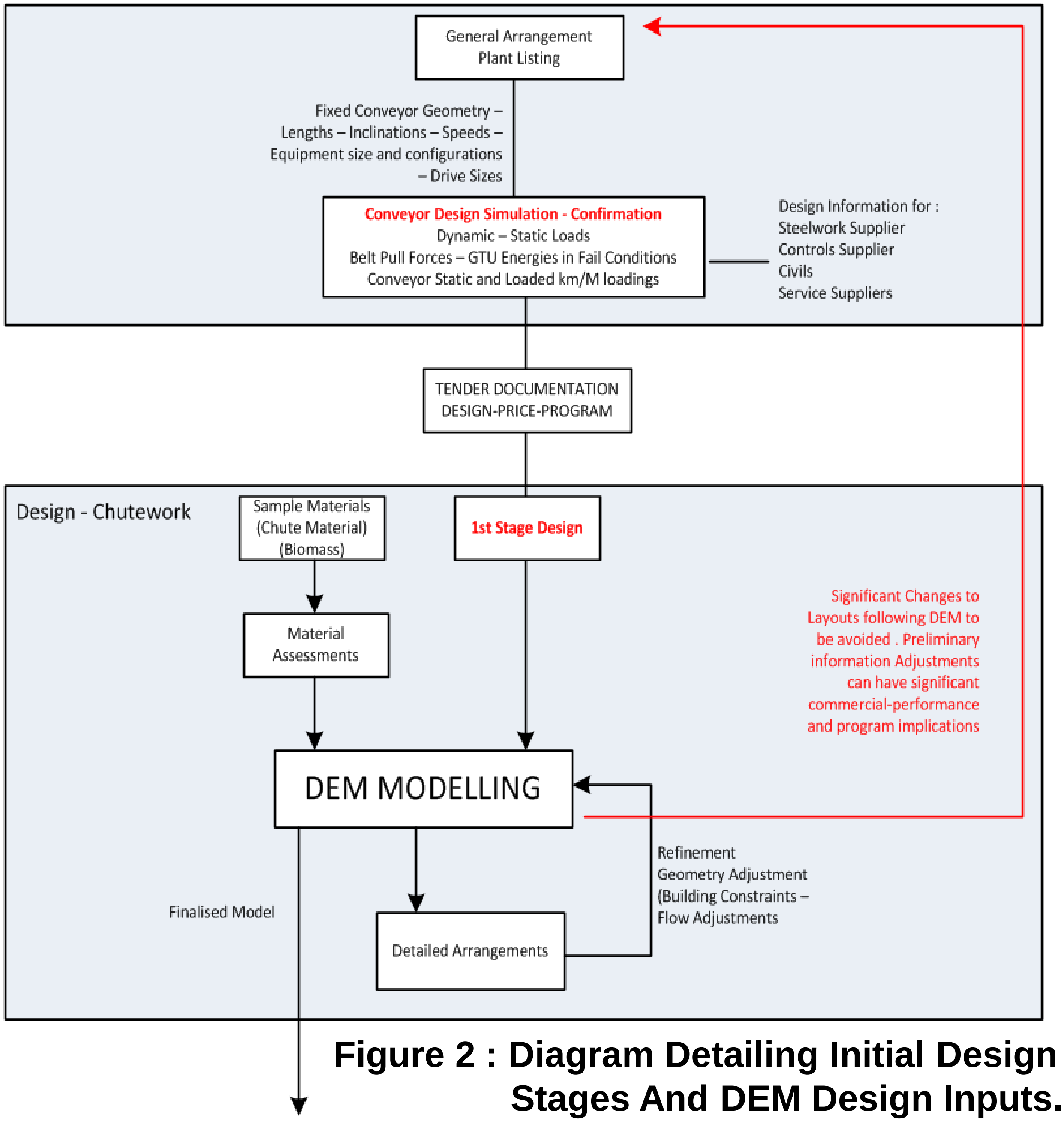

Figure 2 : Diagram Detailing Initial Design Stages And DEM Design Inputs.

Tender Design

- Correctly designed conveyor transfers is fundamental requirement of the fuel handling system.
- Optimising the design of conveyor system transfers is fundamental to a conveyor systems success and reliant on Discrete Element Modelling and Material Analysis.
- Suppliers with prior experience in the design and manufacture and installation of bulk handling solutions of the material, the handling equipment, the design processes and handling the material at the required rates offer significant benefits to the client in achieving “right first time designs”.

Conveyor Transfer Design

A typical Transfer Point comprises of metal chutes that will typically provide :

- Flow Regulation
- Flow Placement
- Flow Containment

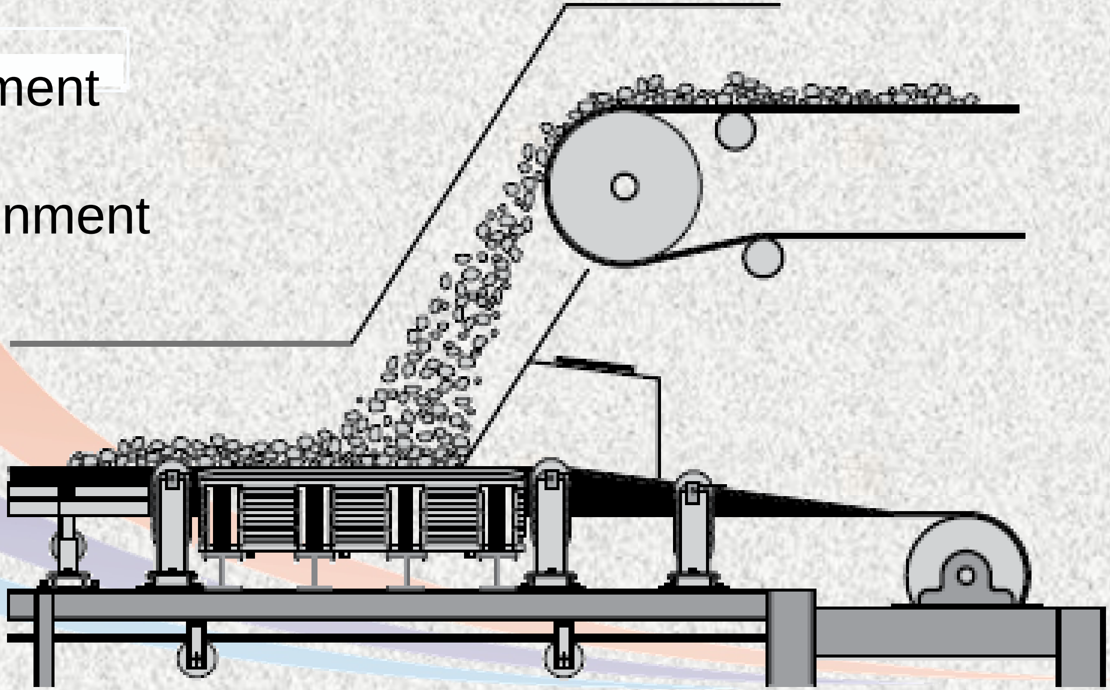

Figure 3 : Diagram showing the conveyor transfer principles

BS8348-CEMA Volume 6

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Transfer Point Challenges

To minimise wear, reduce material degradation reduce dust and component wear a transfer point design will deliver the material

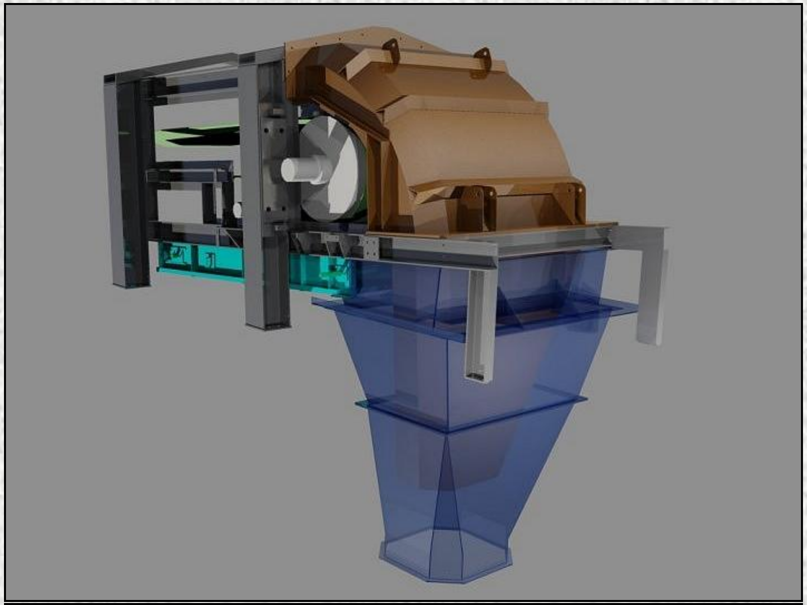
- In the centre of the belt
- At a uniform Rate
- In the direction of belt travel and as near to the belt speed as possible
- Within a fully formed troughed section of belt
- With minimised Impact Force

Engineered Flow Chutes

- The friction between the chute wall – liners and the material
- Adjustments to one aspect of the design directly influence other areas.
- Significant benefits through managed material flow and the control of dust generation and spillage.
- Principles of fluid mechanics and an understanding of particle movement

Head Chute

- A hood captures and confines the material
- Geometry designed with a low impact angle
- Soft tangential presentation of material trajectory
- Minimising internal ledges from material deposits



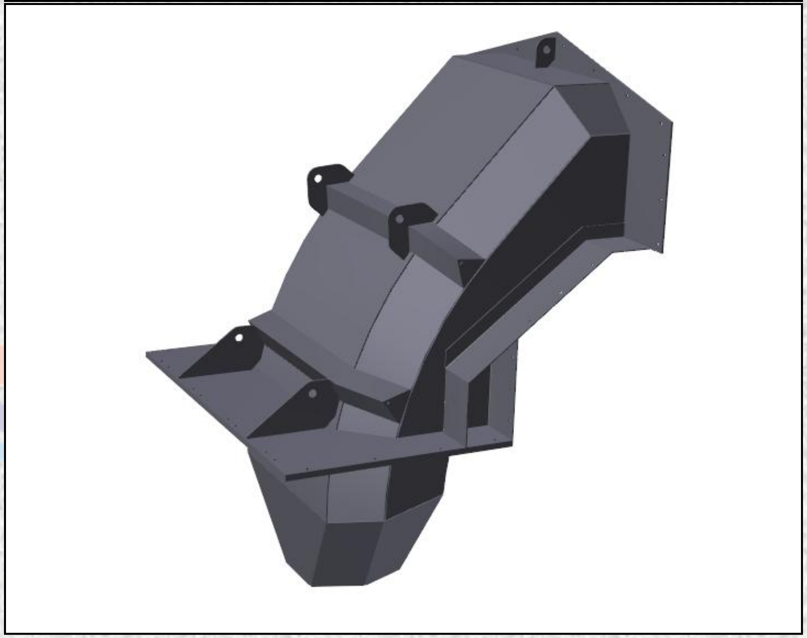


Figure 4 : 3D Illustrations of Hood Chutes

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Spoon

- Installed at the bottom of the chute

- Presents the material stream smoothly and centrally

- Reduces impact on the belt

- Minimises dust and product degradation

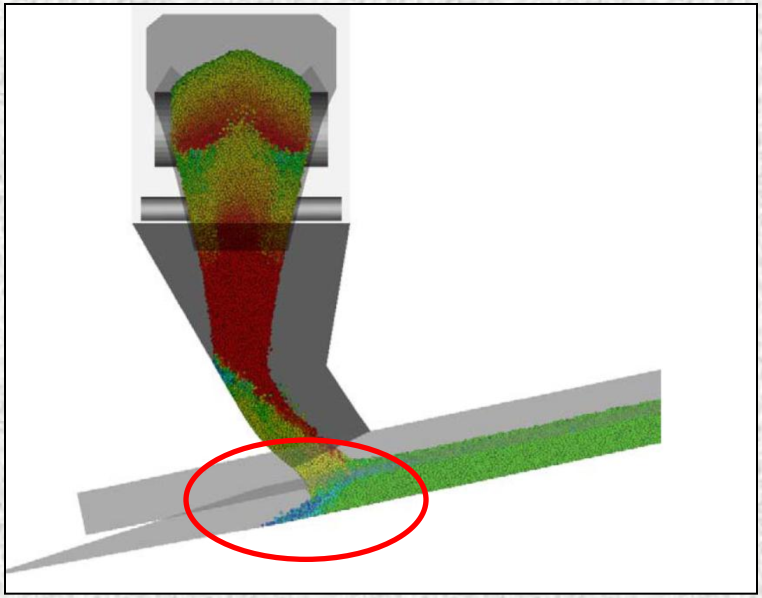

Figure 5 : 3D Illustrations of Spoon Chutes, also showing the deluge gap.

Chutes

Between the Hood and Spoons are chute sections.

- Material stream to remain in contact with the chute surface
- Important in establishing the ideal chute size to minimise fabrication and material costs.
- Conventional design indicates a rule of thumb, "that the chute should be at least four times the materials sectional area at any position and two and half times the maximum product size" to avoid chute blockages.

Engineered Flow Chute Process

Engineered flow transfer chutes are developed with a 3 Stage Process.

Stage 1: Material Assessments

Bulk Density, Material Size, Angles of Repose and Surcharge Angles have been used to size equipment and coupled with conveyor length, speeds and operating angles are a proven basis for establishing peripheral forces and the sizing of drives.

Physical testing of actual materials is of critical importance

DEM Stages

Stage 2 : DEM Process

- Tunra provided conceptual design of Hood, Spoon, Transfer chutes and Bifurcated Transfer Chutes.
- Material Property Analysis was undertaken, covering wall friction, internal friction and bulk density of 3 materials
    - Wood pellets,
    - Peanut pellets
    - Sunflower husk pellets

DEM Stages

- **GA Submission**
  covering conveyor inlets, head discharge positions and the geometry between these two locations.

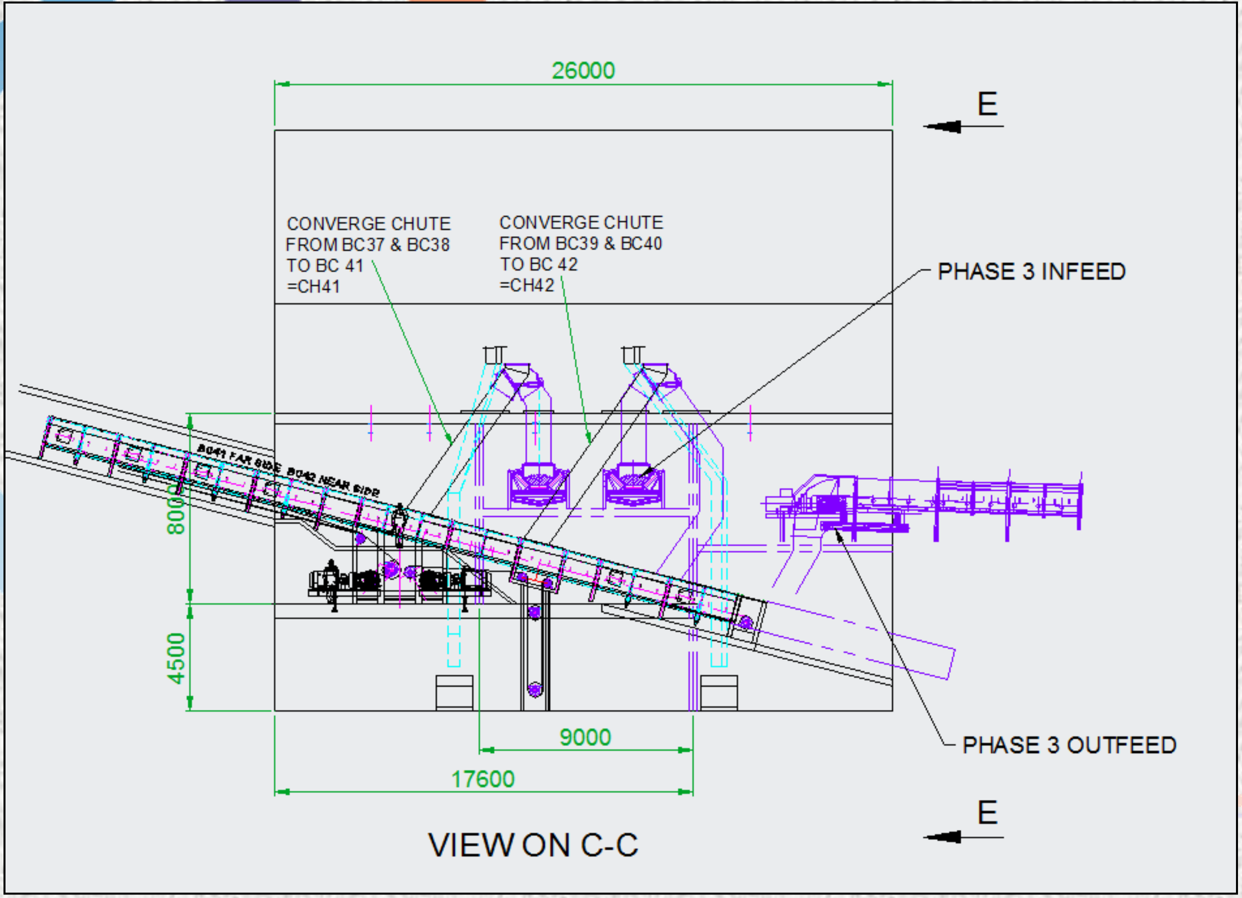

Figure 6. BC37-40 1400mm Discharge Points to BC41 - BC42

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DEM Stages

- **DEM Report** : Conceptual Design, Based on the General Arrangement information, system performance criteria and the data from the Material Analysis,

1.	*Throughput*	*2800 tph (1400 tph per incoming conveyor)*
2.	*Incoming belt*	*BC37 & BC38, BC39 & BC40*
3.	*Incoming belt velocity*	*2.8 m/s*
4.	*Inclination + transition angle*	*4.9°*
5.	*Head pulley diameter*	*640 mm*
6.	*Incoming belt width*	*1400 mm*
7.	*Incoming Carry idlers*	*45°*
8.	*Outgoing belt*	*BC41, BC42*
9.	*Outgoing belt velocity*	*2.8 m/s*
10.	*Outgoing belt inclination*	*14.5°*
11.	*Outgoing belt width*	*2000mm*

DEM Stages

The conceptual Design provides the following reports from the results derived from the DEM Model.

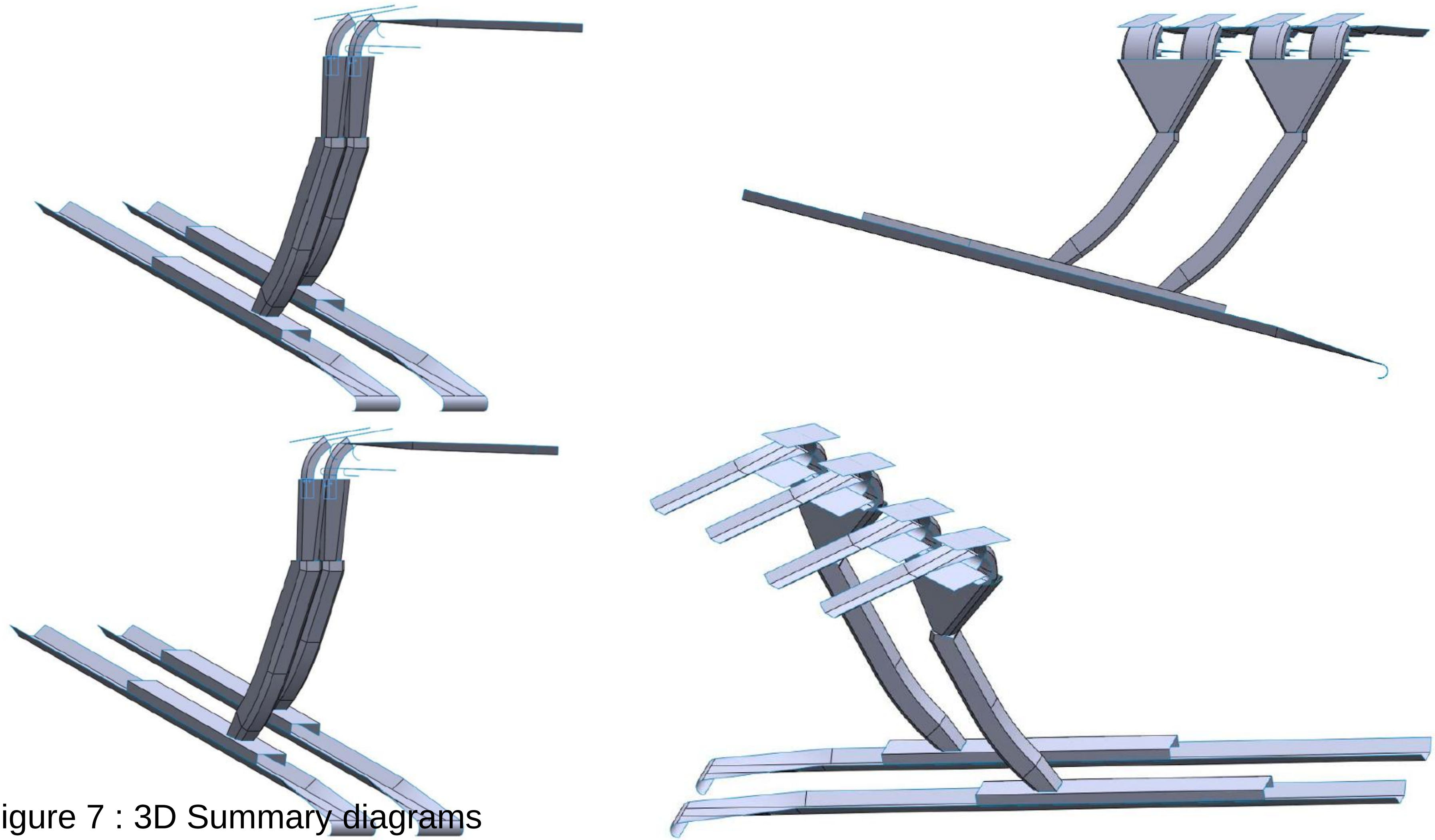
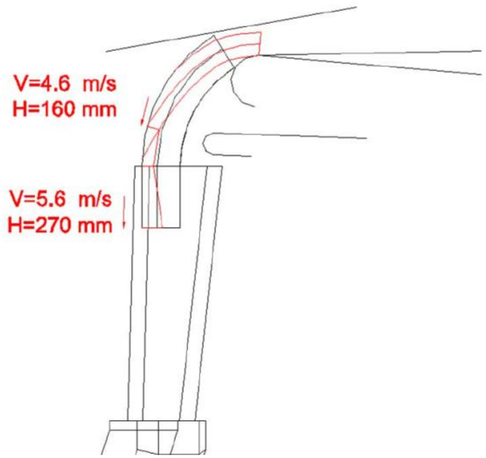


Figure 7 : 3D Summary diagrams

DEM Stages

Continuum Modelling Report : BC37-38 feeding BC41 Transfer.



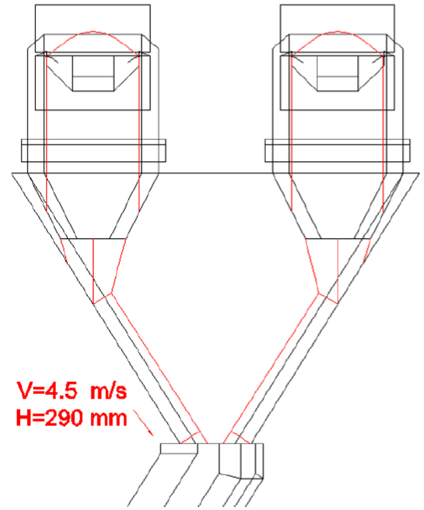
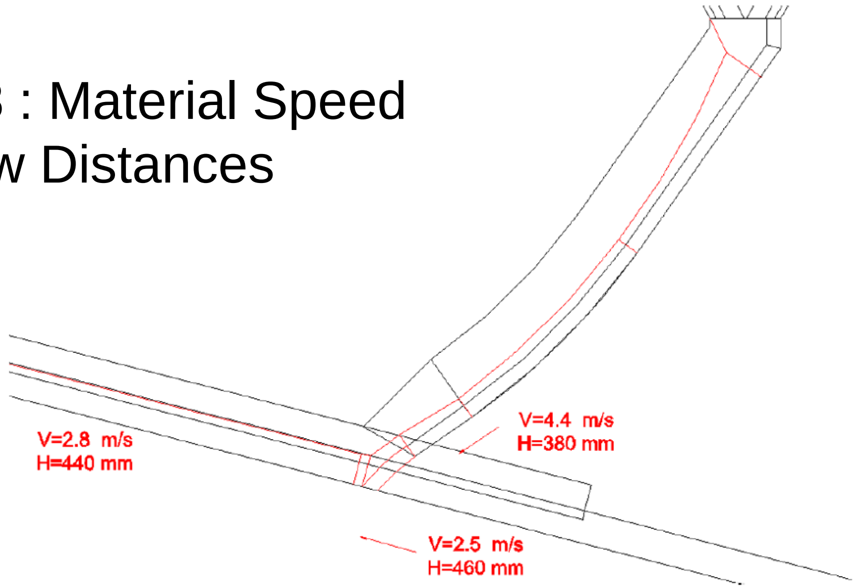


Figure 8 : Material Speed and Flow Distances



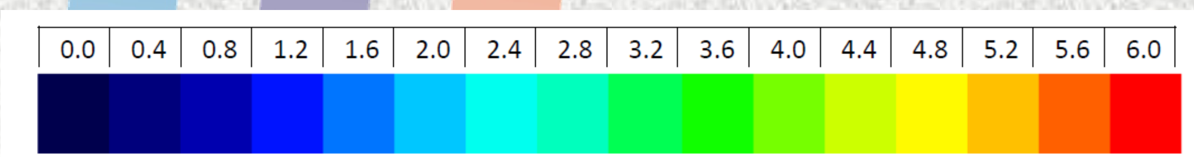
Material Loading the Belt is 4.4m/s which is faster than the receiving belt speed of 2.8m/s. Calculations indicate that the material stream acceleration to belt speed in 0.2s confirming the chute blockage will be avoided.

Figure 8 : Material Speed and Flow Distances

3D DEM Simulation

- Demonstrates flow simulation, with colour coding to differentiate material velocity projections with the chutework.
- Burden depth projections
- Material dispersion effects

Velocity Bar - dark blue indicating zero to low velocity and red indicating velocities of 6.0m/s and higher



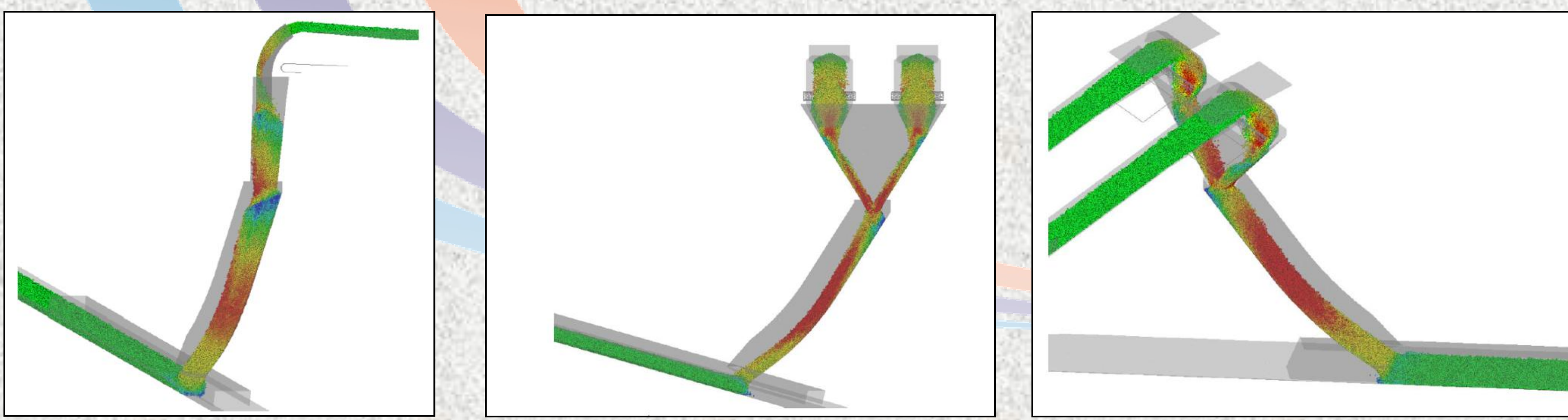


Figure 9 : Velocity Bar - dark blue indicating zero to low velocity and red indicating velocities of 6.0m/s and higher

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Wear Images

- From the DEM simulations contours of wall surfaces indicating qualitative impact and shear wear comparisons are possible.

- Whilst these may be representative of trends of wear the report states that no quantitative assessments should be deduced from the information provided.

- In Simple terms - The higher the number the increased velocity/wear.

Wear Images

Wear Images - The higher the number the increased velocity/wear.

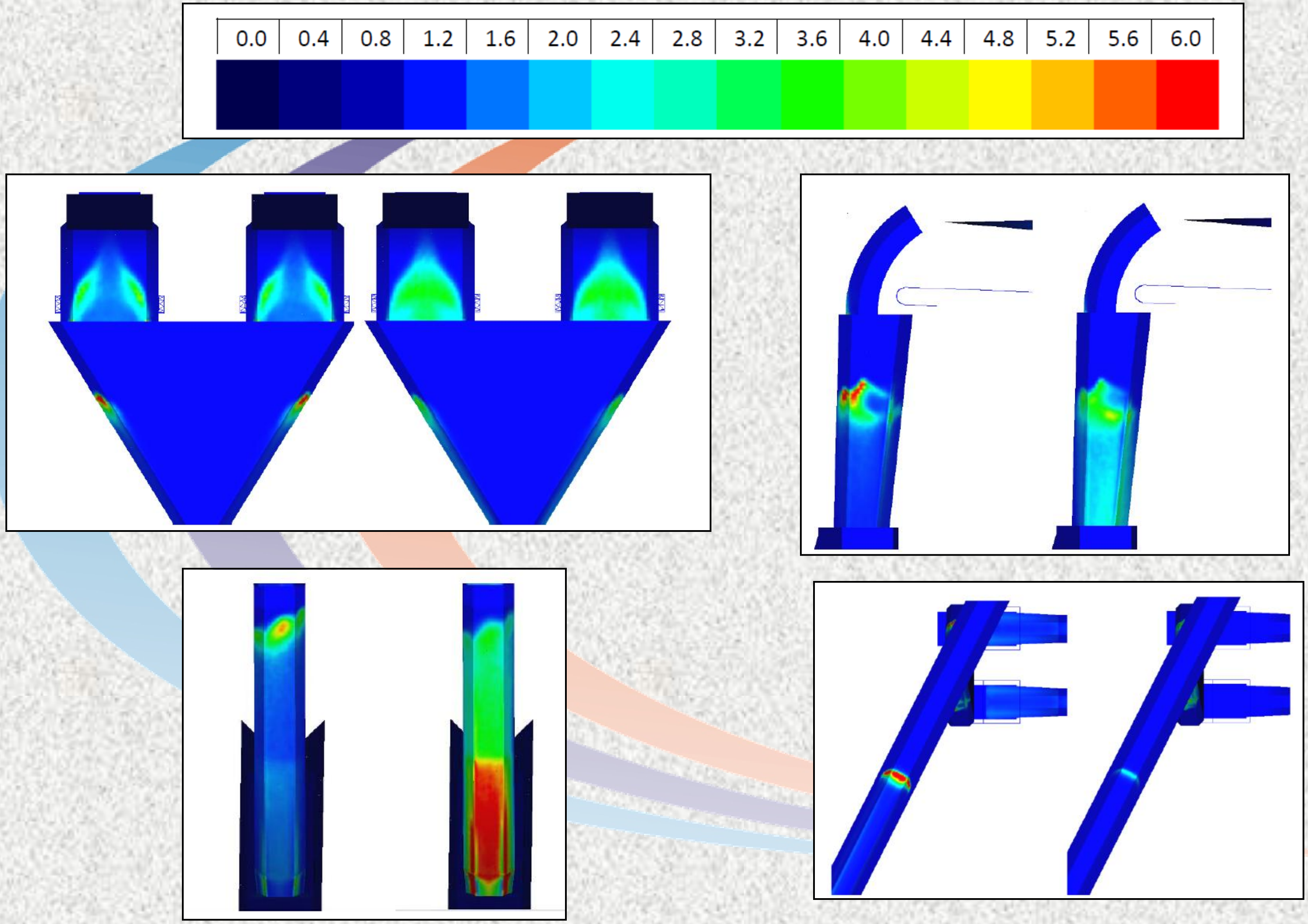


Figure 10 : Wear Images - The higher the number the increased velocity/wear.

DEM Simulation Report

- Provides an effective albeit approximate insight into the visualization of a 3D flow through the conceptual flow behaviour and provides qualifying statements that the chute design provided will ensure efficient transfer of bulk solids without spillage and/or blockages.

- The reported information particularly on wear rates against the 3D models, also enables post installation cross checks to be undertaken with thermal imaging cameras to assess the accuracy of the design.

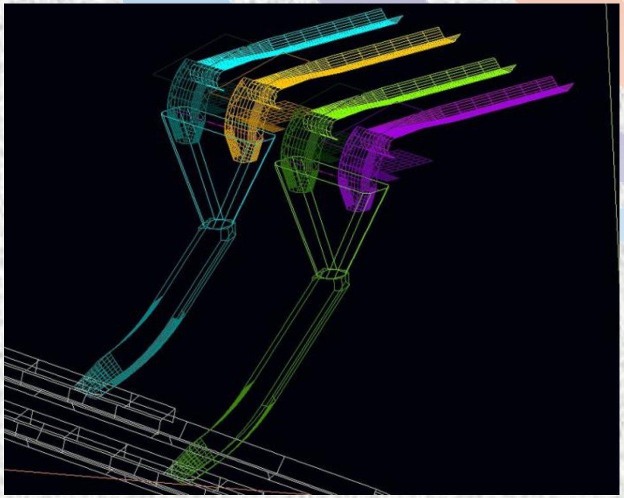
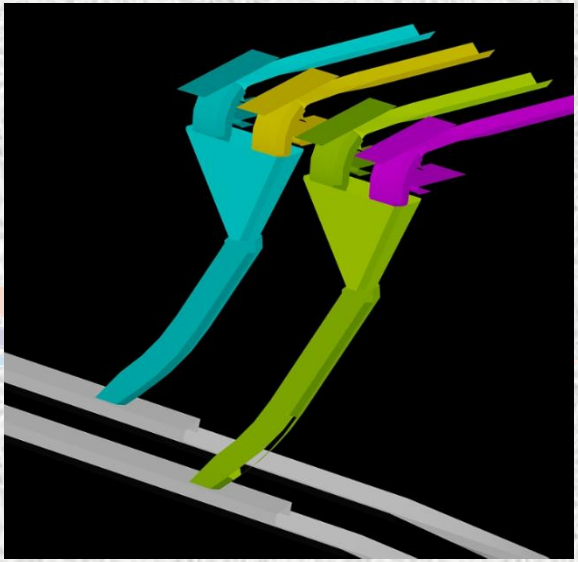


Figure 12 :
Chute geometries



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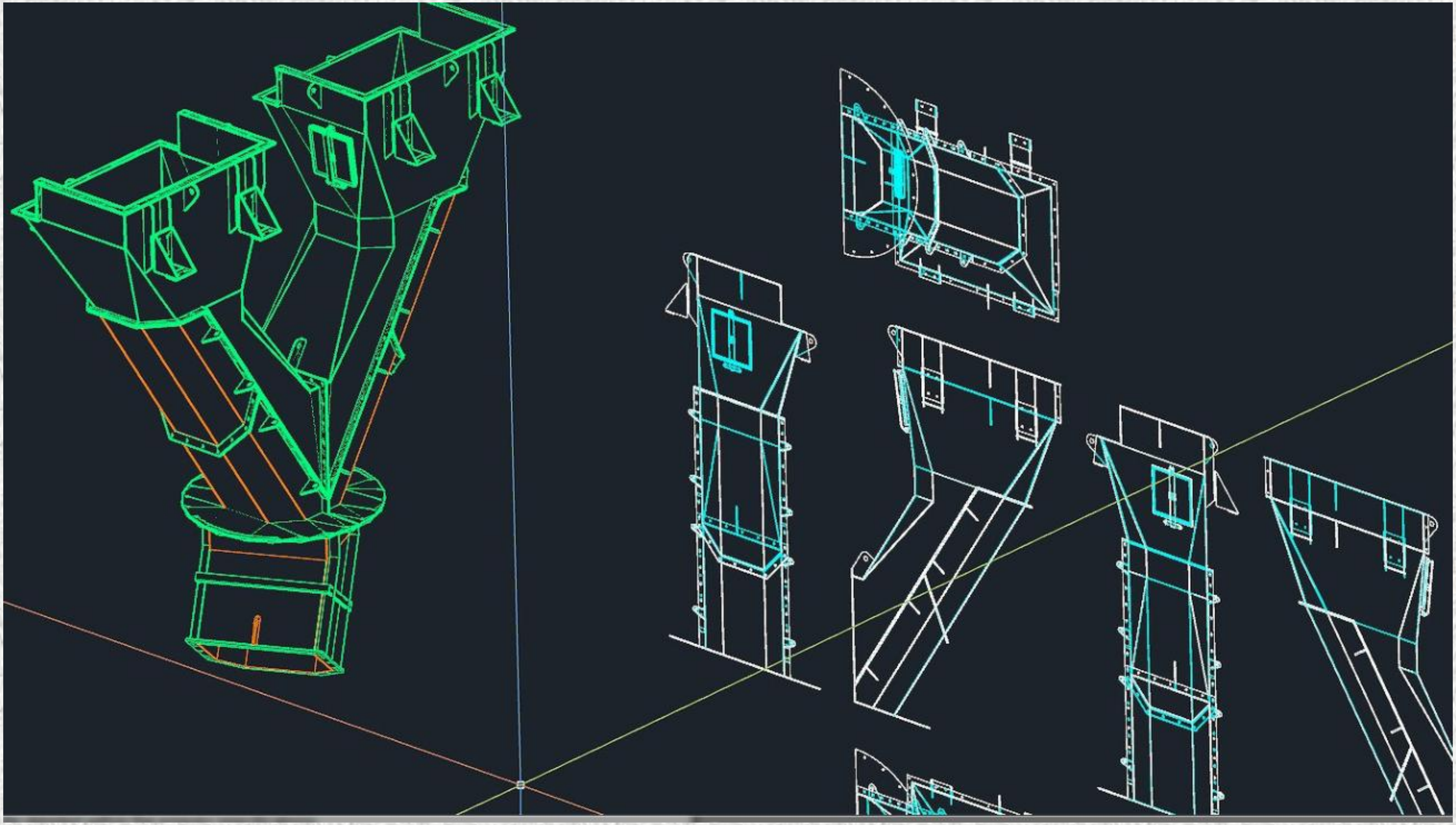
DEM Stages

Stage 3 : Manufacturing Design

- Tunra model is finalized with the 2D and 3D form built electronically, giving a better idea and visualization of how the finished chutes will look.
- The model is created using techniques which exactly mirror those to be used in fabrication of the actual chute. This ensures that the fabrication will be capable of being manufactured.
- Small tolerances in the fabrication and installation of the components can affect the smooth flow of material
- Changes resulting in increased velocity occur this can also result in increased wear and dust propagation

Manufacturing Design

Figure 13 : 3D and 2D Drawings



Manufacturing Design

The designs are very accurately and fully modelled, to ensure suitability, but primarily to allow clean and accurate 2D detail drawings to be taken quickly and directly from the 3D model.

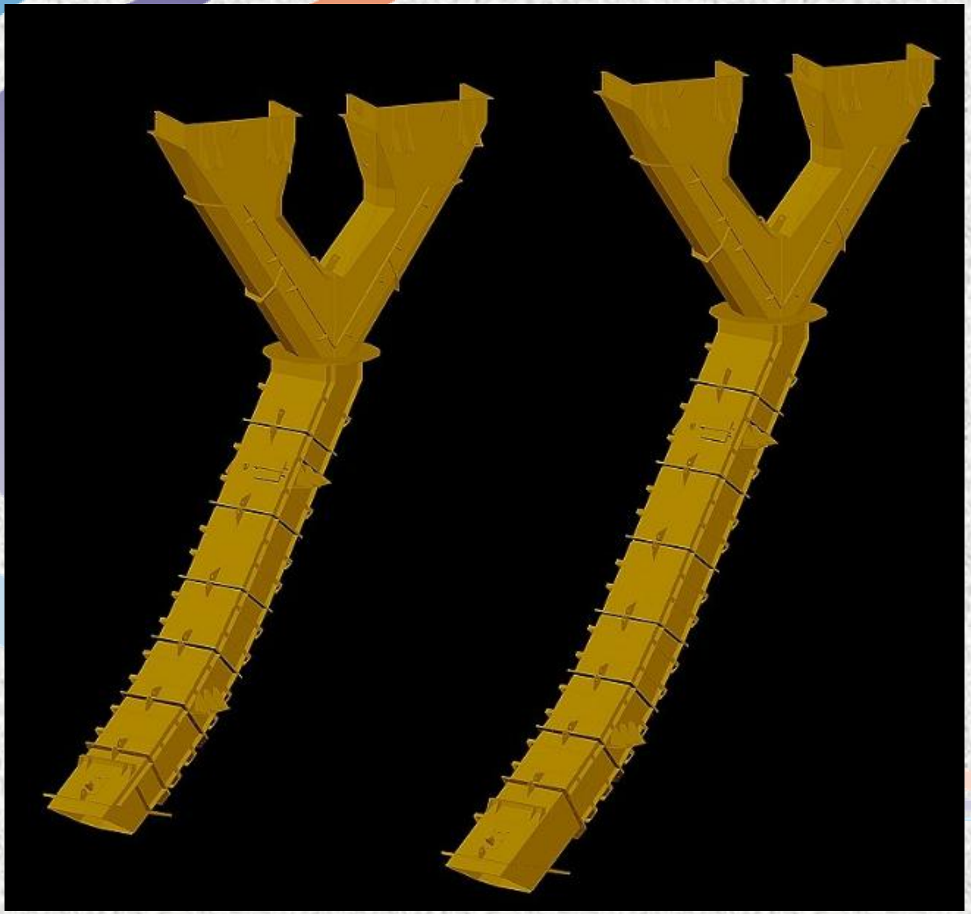


Figure 14 : Manufacturing 3D Model

Chutework Material

- Impact and abrasion are primary contributors to chute wear.
- Wear within chutes formed a key aspect of the project design with onerous performance criteria for chute wear life detailed within the enquiry specification.
- Woodpellets are classed as a highly abrasive product.

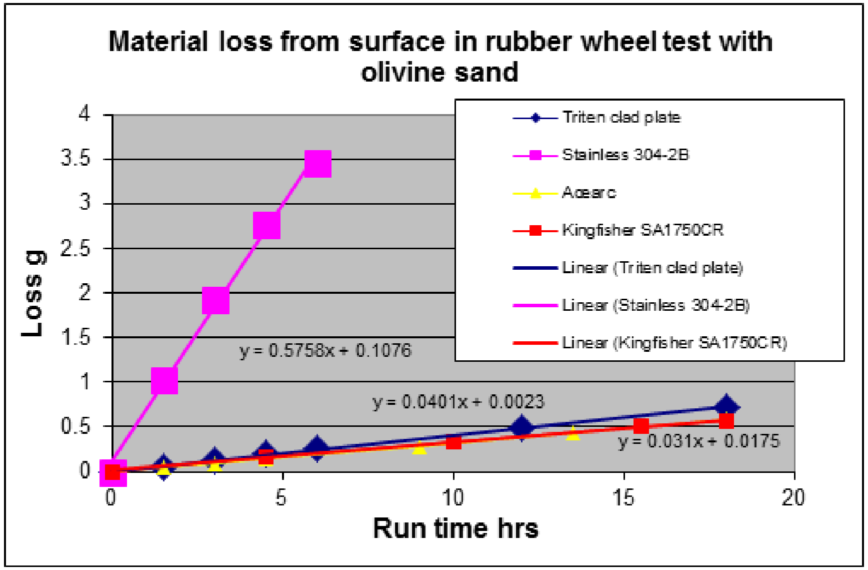


Figure 15: Material Loss Graph

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Chutework Material

The Chute Hardened Plate has been developed to combat abrasion, erosion and impact at either ambient or elevated temperatures. The range comprises different hard facing carbide alloys deposited onto a carbon steel or substrate.

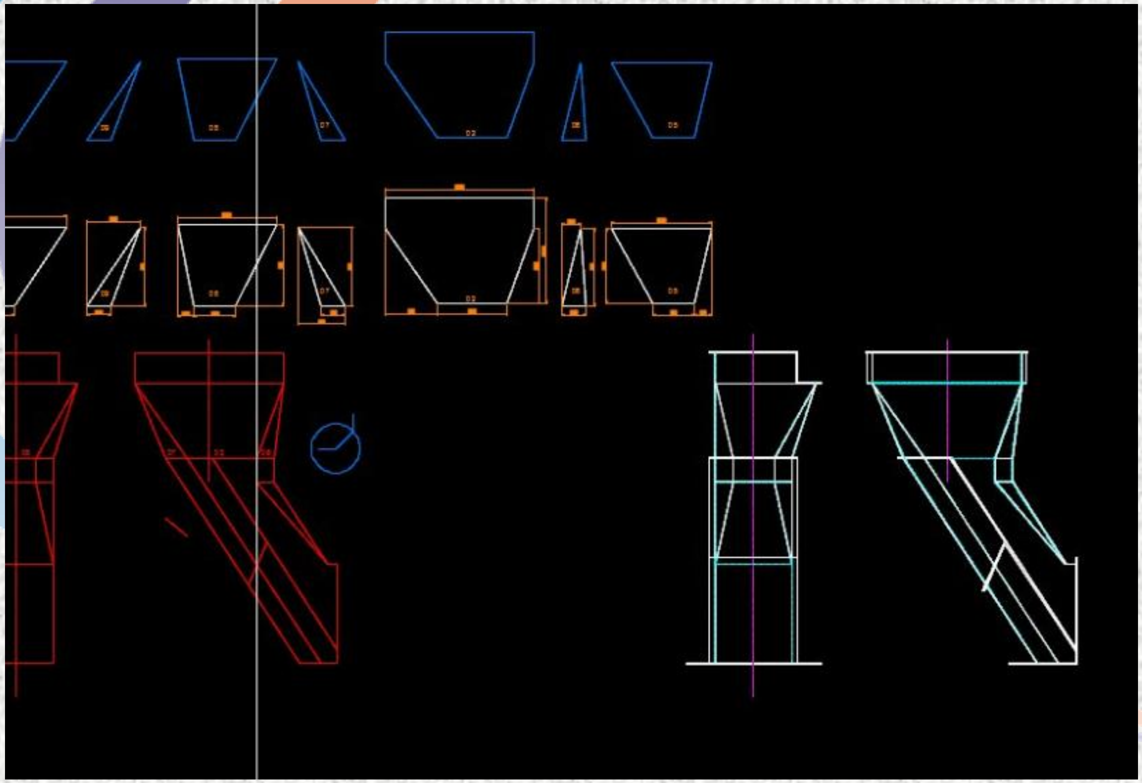
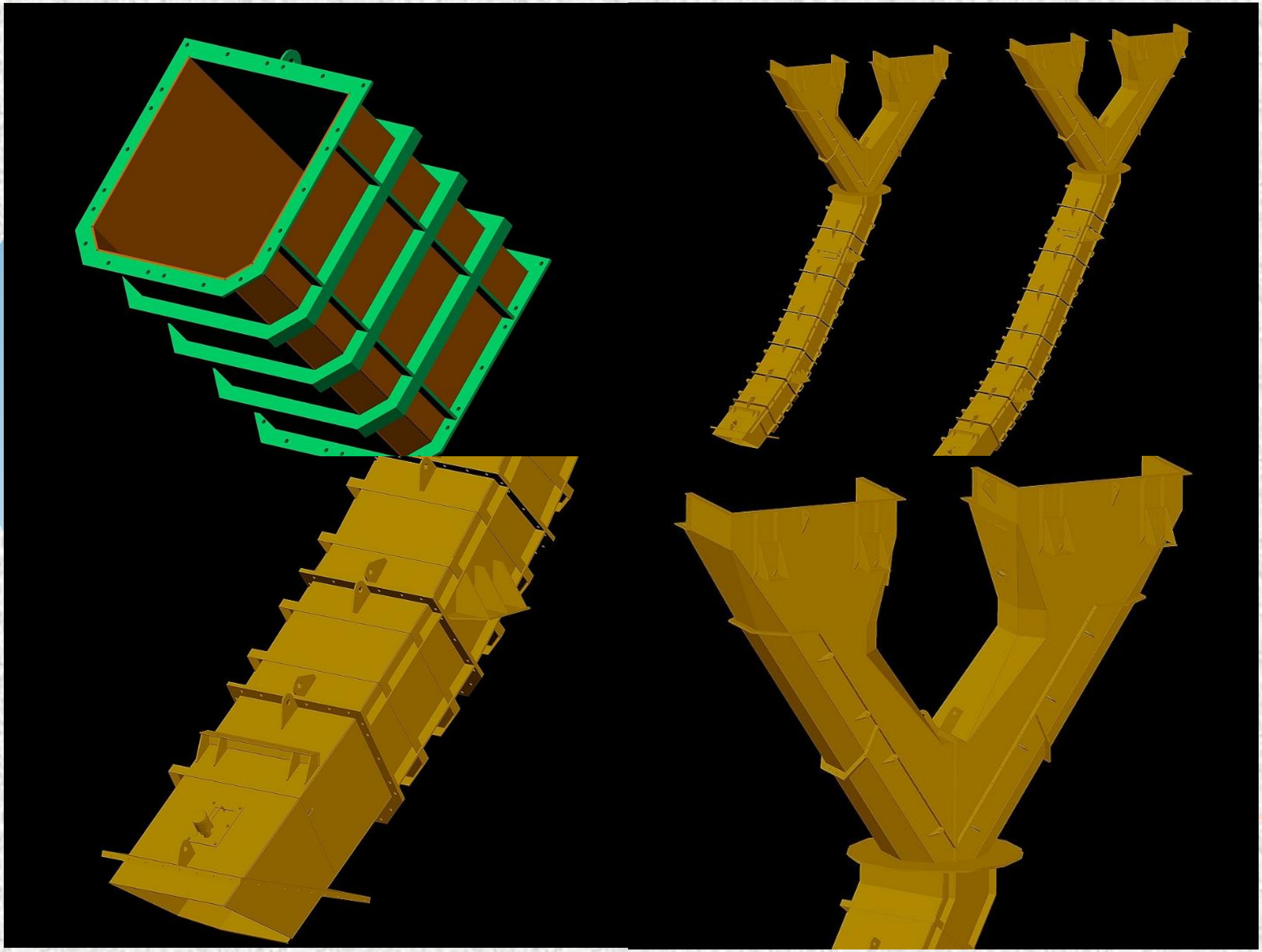


Figure 16 : Chute Profile Drawings

Chutework Material

Figure 17 : 3D Chute Profile Drawings



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Commercial Assessment

Activity Analysis :

Activity :	Conventional Chutework	Engineered Flow Chutes
Material Analysis	Not Done	Undertaken at Early stages in project - 1 off Report and costs
DEM - 3D Model and Report Assessment	Not Done	Undertaken for each chute - Initial Report and 3D model Chargeable c.w re-assessments of design changes
3D Model Conversion and Fabrication Design	Not Done	Undertaken by Plant designer - Assessing each report - feedback and 3D conversion
Manufacturing Drawings	Produced from GA	3D model once exracted - 2D fabrication Drawings in line with std chute design (Excluding additional strengthening)
Chutework Material Costs	Stainless Steel / Liners	High Carbide wear Plate and profiling typically x% higher than mild steel
Installation	Comparable	Additional Access Design and Costs saved on Engineered Flow Chute Design when using fully fabricated Hardened Plate.

The above chart provides an indication of the additional activities and cost consideration associated with Engineered Flow Chutes over conventional chute design, with mild steel chutes fitted with liner plates.

The Design costs for Material Analysis is a typical 1 off cost that will provide a material assessment representative for all areas of the conveying system.

The DEM costs are based on a costs for each piece of work comprising of each transition section between conveyors. Where practically possible standard designs on conveyor geometry within a given system should be attempted to save DEM costs.

The Costs For Failure

Tangible results within a totally enclosed conveying system can be difficult to measure until a sufficient volume of material has been handled over a period of time. This is also based on comparisons to previously installed chute designs, which in new build provides no datum.

In the context of the Drax ECO-Store project, DEM modelling was considered necessary to avoid blockages, severe increased wear rates in chutes, pellet degradation and dust propagation due to non linear conveyor transfer points, belt speeds, high volumes and the transfer heights.

Based on this the conveyor systems ability to ensure a consistent managed flow is the marker for success as opposed to blockages, high wear, and high levels of dust.

Chute Problems

- During the commissioning stages of the project scorch marks were visible on a chute.
- The scorch mark was a small localised area at the bottom of a long chute drop and the location aligned with the expected material trajectory of the DEM model and was repeatable.
- The temperature increased as the throughput increased based on fixed speed variable burden.
- At 2800Te.Hr heat was detected on the outside of the chute confirming a problem of heat build up.
- At lower speeds and or less material burden the heat issues were significantly reduced.

Chute Problems

In Simple terms - Higher the number the increased velocity/wear.

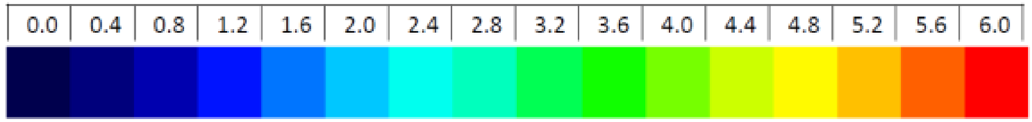
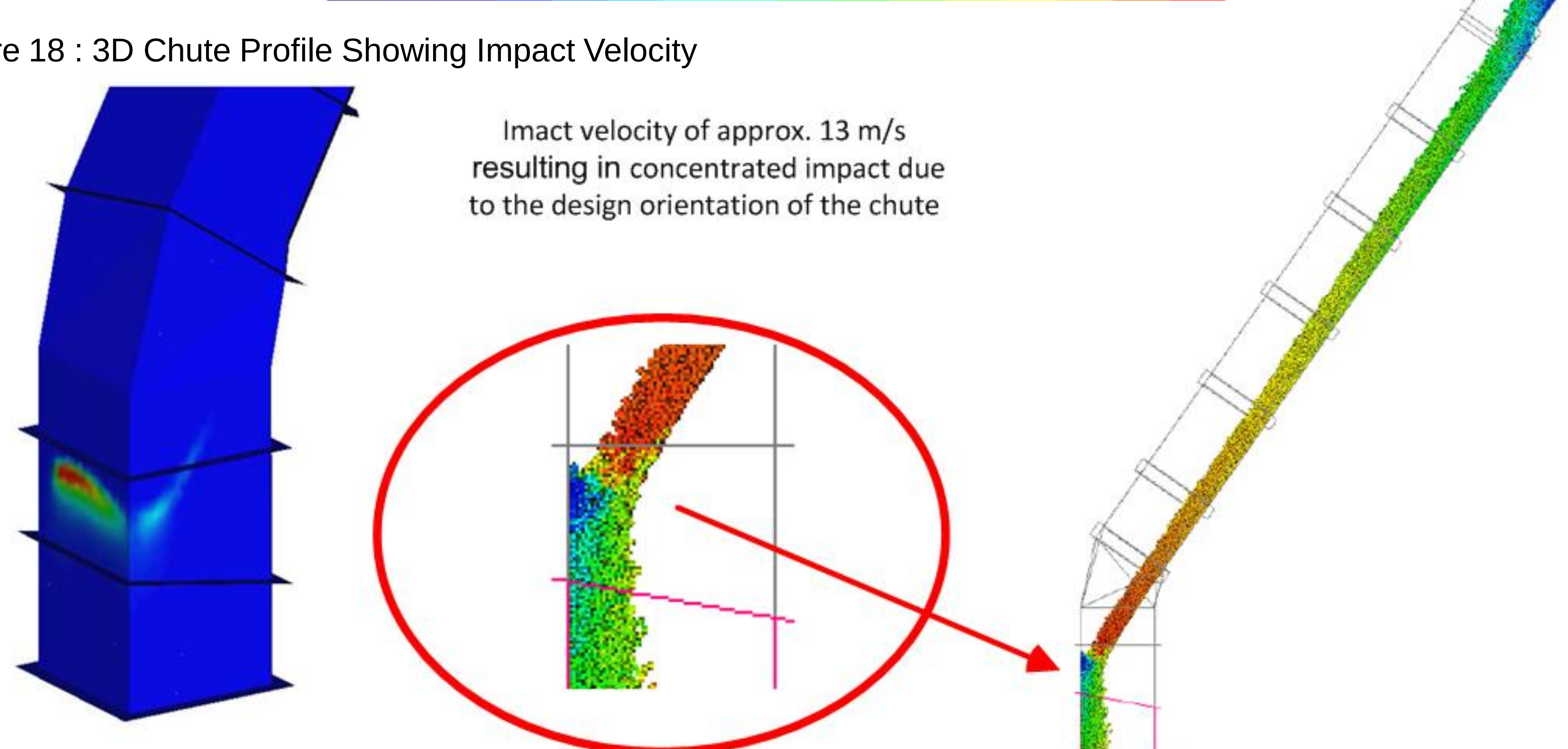


Figure 18 : 3D Chute Profile Showing Impact Velocity



A detailed assessment using infra-red cameras to measure the temperature of the outer casings was then undertaken and results checked against the Tunra models to check the hot spot locations were in line with the Tunra model locations.

Chute Problems

- Robson along with The Wolfson Centre and Tunra Engineers reviewed the design and various options were reviewed to reduce the heat.

- A design assessment of the chute geometry was undertaken and concluded that the specifics of a very tight concentrated material cross section, high impact velocities and the high impact angle due to a compromise in the conveyor geometry were the reasons.

- The high insulation properties of the woodpellets and high friction co-efficient of the material and chute wall with high impact force in concentrated area and the slowing down of product velocity on impact resulted in high energy loss being absorbed into the chute wall.

Redesign

A re-design of the chutework in this area was undertaken, based on providing a mid section of chute with a necked down cross sectional area to provide shallower angle.

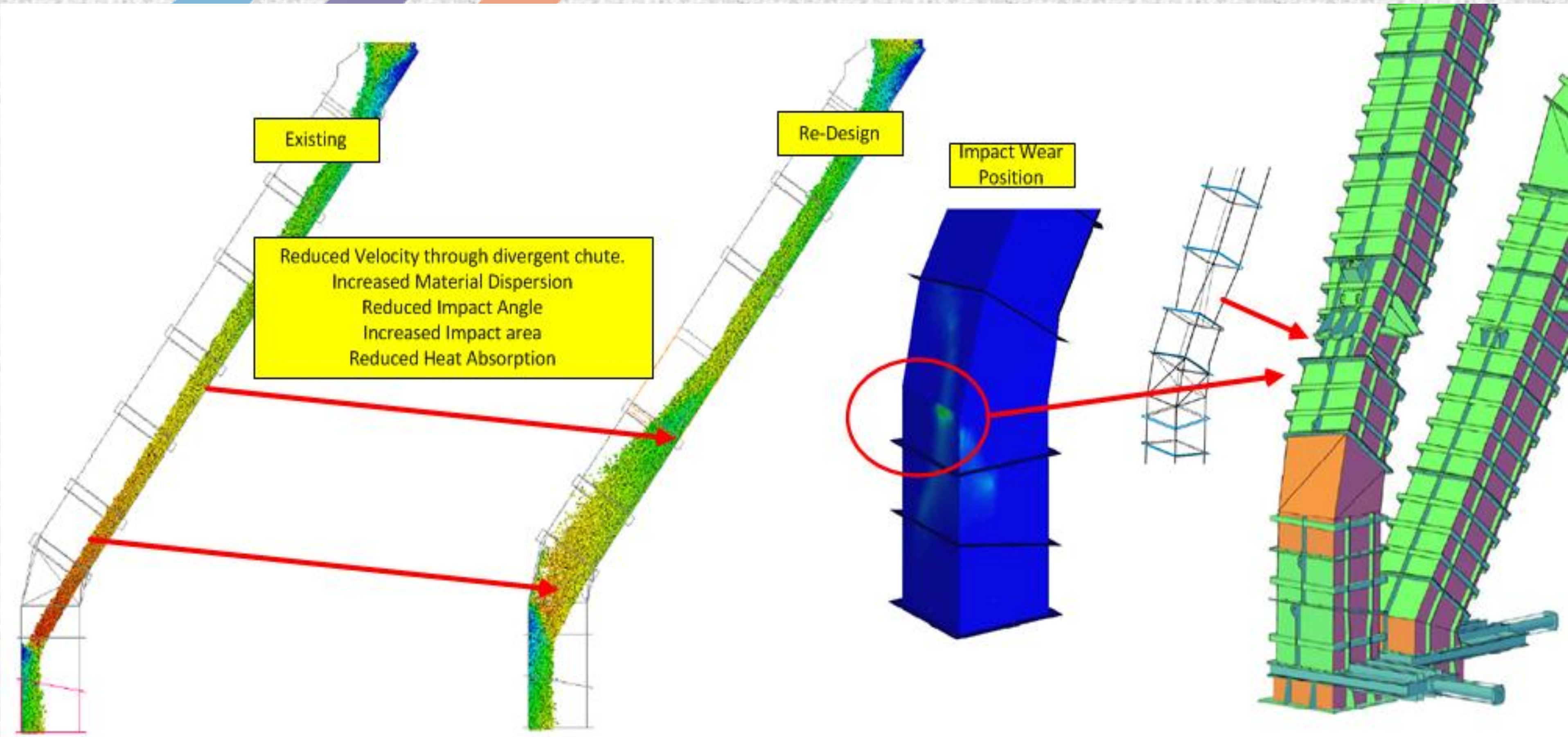


Figure 19 : Chute Redesign

Observations

The Discrete Element Modelling (DEM), Material Analysis and subsequent chute design performance can be measured in terms meeting the design objectives:

- Chutes not blocking
- Maintaining a centralised feed onto conveyor inlet sections
- No back rolling of material below spoon chutes

The limitations of the DEM and Material Analysis are:

- No evaluation of the heating effects are considered within the DEM analysis.
- Whilst a correlation between impact areas and velocities is provided to indicate the extent of areas and scaling of severity, no value or range of expected temperature is provided.

Until an accurate representation of the heat effects of chutework can be provided within the DEM model, physical inspections will be necessary on completed work to validate the design which is limited and problematic given the range of variables.

Observations - DEM Opportunities

- The inlet section design is fundamental to ensure mass airflow and associated dust is contained.
- Airflow suppressed to below a 1m/sec, flow rate allows dust to settle into the material prior to leaving the transfer point.
- High fines content, dictates air flows less than 1m/sec should be targeted.
- An accurate understanding of the fines content is required.

Observations - DEM Opportunities

DEM Modelling Opportunities to establish Airflow and inlet section transfer design.

Total Airflow within a transfer point can be calculated via the expression :

$$Q_{tot} = Q_{dis} + Q_{ind} + Q_{gen}$$

Where :

Induced Air :-

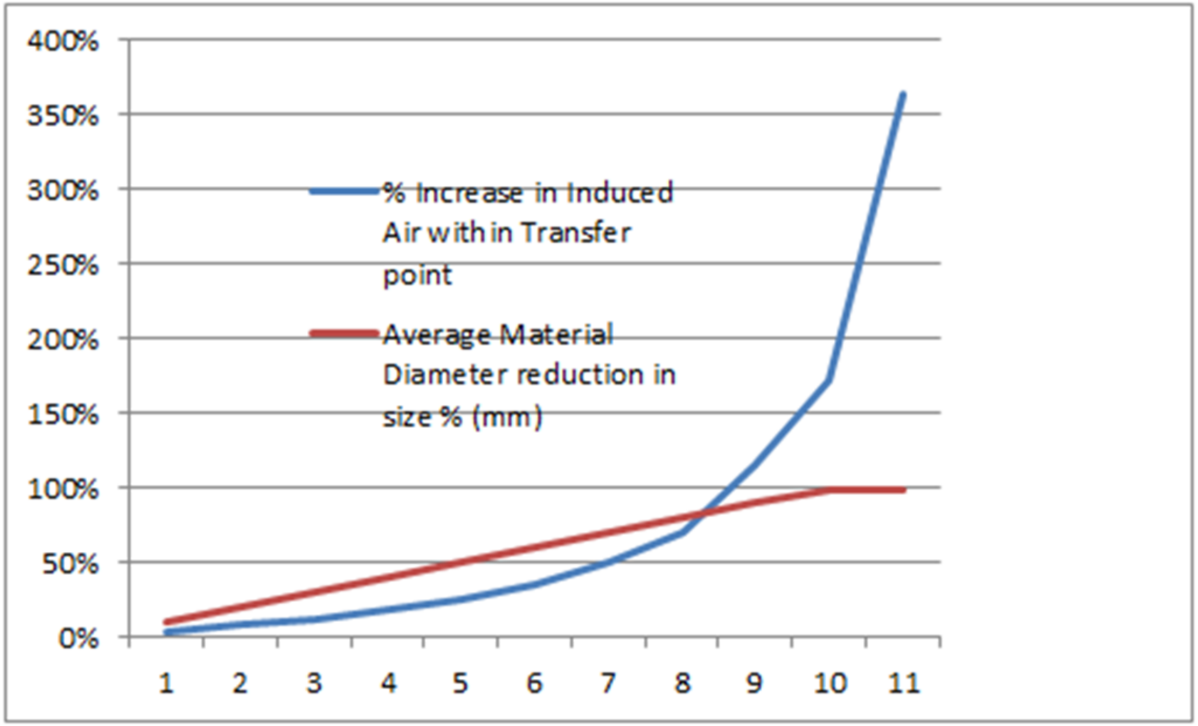
$$Q_{ind} = k \cdot A_u \cdot \sqrt[3]{\frac{RS^2}{D}}$$

The volume of Induced Air (Qind) is a function of the open ended Area (Au), the rate of flow (R), drop height (S) and average material diameter (D). (K=Conversion Factor)

Observations - DEM Opportunities

As Average Particle Size Reduction vs Airflow Increase

Impact of Fines with Material Stream - High Proportion of Fines = High Induced Air



Pellet diameter reduction increases Induced Air (Qind) exponentially.

Limiting Particle size in Material Assessments and Discrete Element Modelling restricts accuracy of the results in materials with High Fines Content

Volume of Induced Air (Qind)

Figure 20 : Particle Size Vs Airflow

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Observations - DEM Opportunities

Based on the above calculation it can be seen that reductions in particle size increase the Induced Air within the product exponentially.

Qgen :

The rate at which the air is then displaced is based Qgen a factor of the drop height, impact forces, changes in direction and cross sectional area of material. Representative Information of Qgen would expect to be provided available within the DEM model. This information is not available from the Tunra model.
Displaced Air (Qdis) :

$$Q_{dis} = \frac{k \cdot L}{\rho}$$

L= Throughput (Te/hr)
P= Density Kg/m^3.
K=Conversion Factor

Pellet Degradation Effects

- The Material Analysis data is used throughout on all DEM models with no allowance for progressive product degradation effects on downstream transfers.
- A variance in pellet quality to be represented within the DEM to assess flow behaviour would be more representative than pre-loaded samples.
- An understanding of the allowed bandwidth in material variance and the expected DEM results would be useful to the designer.

Heat Dissipation

DEM makes no allowance for heat displacement with assessments based on the correlation of impact and velocities from the model which are not considered representative of energy/heat conversion due to omission of chute material properties and other factors.

The need for the link between impact and velocity to be more closely correlated to heat issues, is confirmed within this report through hotspots detected post installation.

Variances in Speed and Throughout

Given the very tight margin between success and failure as detailed through Hotspots design a bandwidth of performance should be understood.

An understanding of the allowed bandwidth in Speed and throughout would be useful to the designer.

The DEM does not provide a bandwidth of performance the results are based on a specific set of results and effects such as speed change +/- %, Material Burden +/-% and pellet size adjustments +/-% worse / better improved pellet sizing would be useful given the data is based on select data.

Chute Sizing Opportunities

Aspects of the design considered issues within conventional chute transfers, (High and non linier transfers) within the DEM process through optimized flow design have enabled material cross sections to be adjusted through balancing velocities, surface co-efficient via gravity and geometry.

Closer integration between the bulk handling system designer and DEM, will enable more efficient chute designs to be realised including a better appreciation constraints of manufacturing and material limitation.

Furthermore opportunities to minimize cross sectional areas of material and likewise the chute cross sectional area within a system handling woodpellets, via DEM are available increasing routing options, chute costs, reducing dust propagation and pellet degradation.

Summary

Material Analysis and DEM has provided optimized chute design, successfully within a high volume, high speed conveying system with non linear transfers and long transfer sections.

Through DEM optimized designs in chutes and transfer points can be realised and produced effectively, providing major benefits to the bulk handling system.

Through accurate designs the additional costs associated with hardened plate fabricated chutes can be offset against permanent access provisions for replacing liners in conventional chutes, when design life of chutes is considered.

As technology advances further opportunities to progress the DEM of engineered flow chutes will be realised to progress conceptual evaluation of airflow and heat transfer characteristics to be assessed and modelled.

Close working between the DEM and Bulk Handling System Designer will through shared knowledge and appreciation enable more cost effective chutes to be provided.

The limitations of the existing technologies it is essential to ensure installed systems are measured via manual and established means as total reliance must be appreciated and worked around

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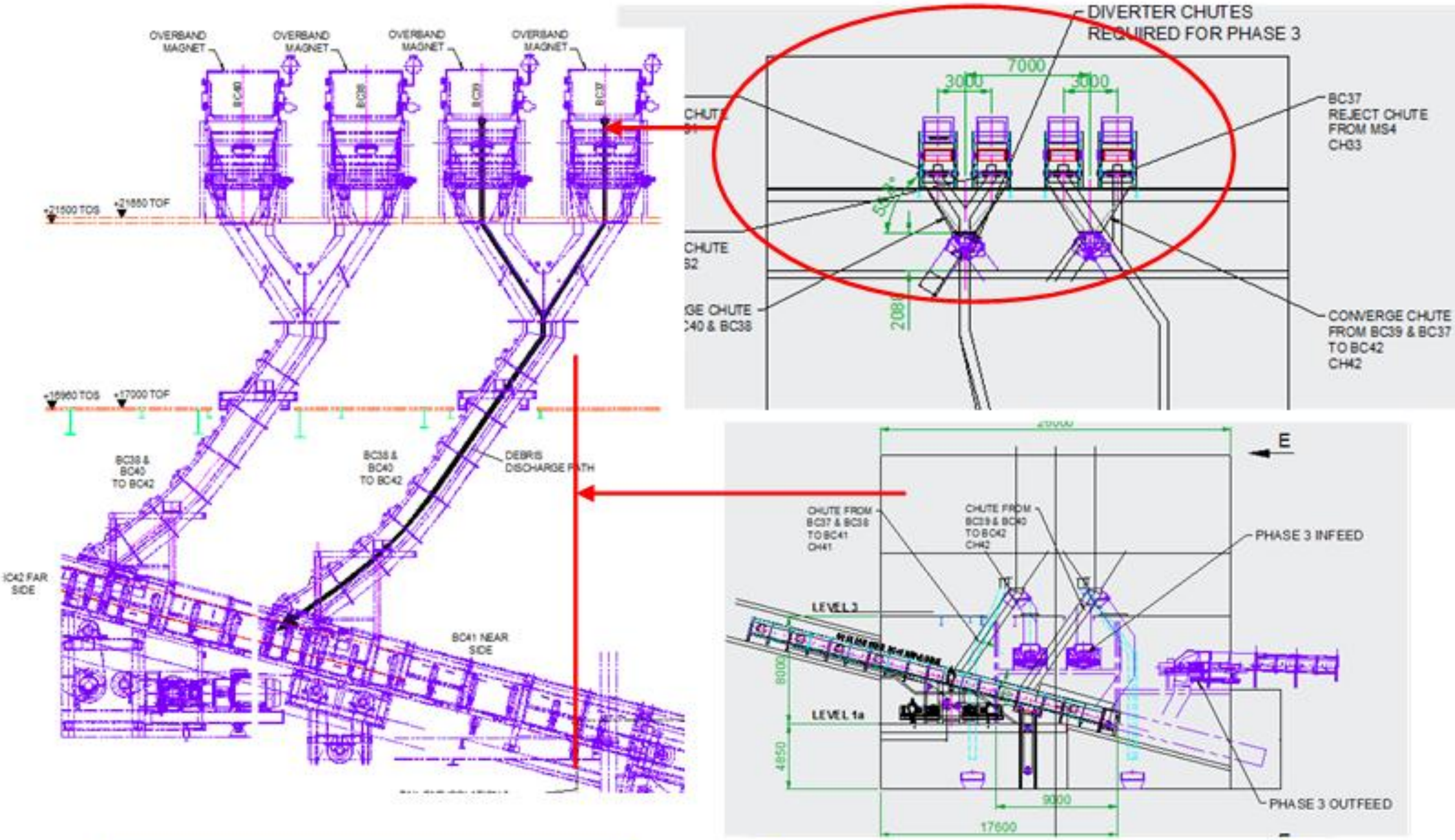
Design Progression using DEM

Figure 21 : Design Progression using DEM



AS BUILT LAYOUTS WITH DEM

TENDER LAYOUTS

Transfer Chute Detailing Comprised Geometry

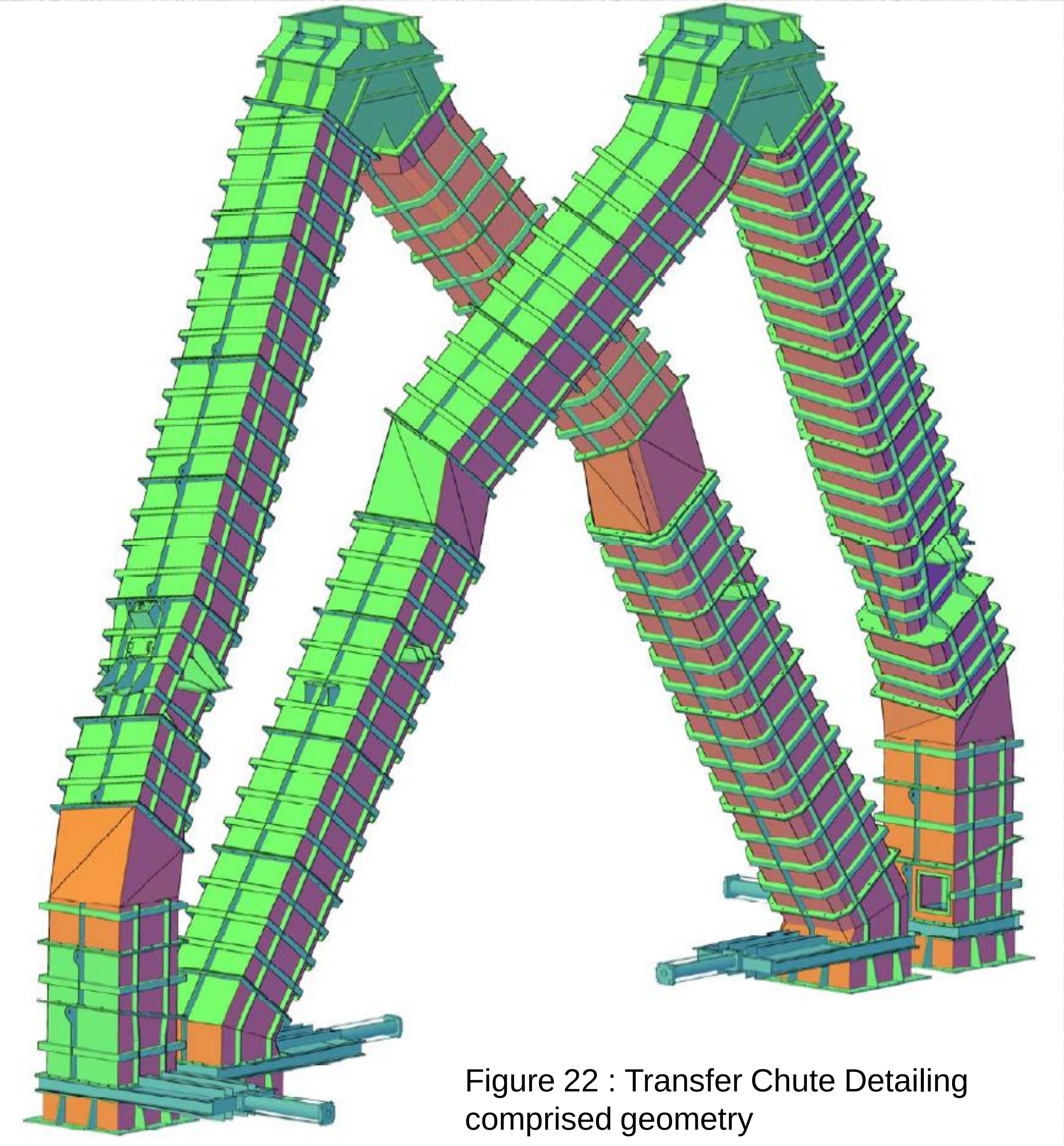


Figure 22 : Transfer Chute Detailing comprised geometry

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Thank You