BORAL ACM Concrete Overlay Engineering Procedure

Document Name:	**PROTOCOL FOR THE INSPECTION OF PLANT STRUCTURES**
Reference:	ENG-PRO-032 r4
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1. Purpose

This protocol sets out the procedure to be followed for visually inspecting and reporting on the integrity of Plant Structures. The protocol is designed so that inspections carried out by different inspectors can yield a consistent risk assessment.

2. Scope

The protocol:

(a) provides a procedure to identify Structural Elements that may present a potential risk to safety, the environment, and operational security;

(b) provides a process by which to rank and report on the condition of Structural Components and Structural Elements; and

(c) provides a process for particular areas for concrete and quarry plants.

3. References

ENG-FRM-032: Form for recording an inspection

4. Definitions

Plant Structure	A fixed structure used for batching operations and predominantly made of reinforced concrete or steel or a combination of both.
Structural Component	A component of a Plant Structure.
Structural Element	Each of the following materials and matters relevant to a Structural Component: (a) Reinforced concrete; (b) Steel; (c) Removal, modification or installation; and (d) Design and construction.
Condition Category	A ranking given to a Structural Element and Structural Component on the basis of the ranking scale set out in section 7.2.

Suitably Qualified Engineer	Person eligible for membership of the Institution of Engineers Australia, preferably one with structural engineering experience.

5. Use of photographs

Some of the photos shown in this procedure are of Boral assets.

6. Background

Engineered structures present in asphalt, concrete and quarry plants are designed to support extremely heavy weights while resisting the forces accompanying movement and vibration. Therefore, inspecting structural integrity is of major importance.

Structural integrity, by nature, is a very important consideration on all worksites. It is therefore imperative that specific strategies are implemented to assist us meet our obligations under safety and environmental legislation.

The audit has been broken into several categories with a Condition Category to be assigned to each.

In order to correctly rank the condition of the item under consideration, photos are presented at Appendices A-D which illustrate typical conditions so that the marking/grading (risk assessment) is consistent.

The audit also contains a section of areas throughout concrete and quarry operations that require particular attention.

7. Process

The inspection should be approached systematically and all Structural Elements should be inspected. A diagram demonstrating the inspection process is provided at paragraph 7.1 below.

A separate form (ENG-FRM-032) should be completed for each Structural Component of the Plant Structure. Three hypothetical examples of completed inspection forms are included in Appendix F. If a Structural Element is assessed such that it may present a medium/high risk, it is imperative the sheet be fully completed with photographic support.

The form provides for a Condition Category to be assigned to each relevant Structural Element and an overall Condition Category to be assigned to each Structural Component. The basis for each Condition Category that may be assigned is set out in paragraph 7.2 below.

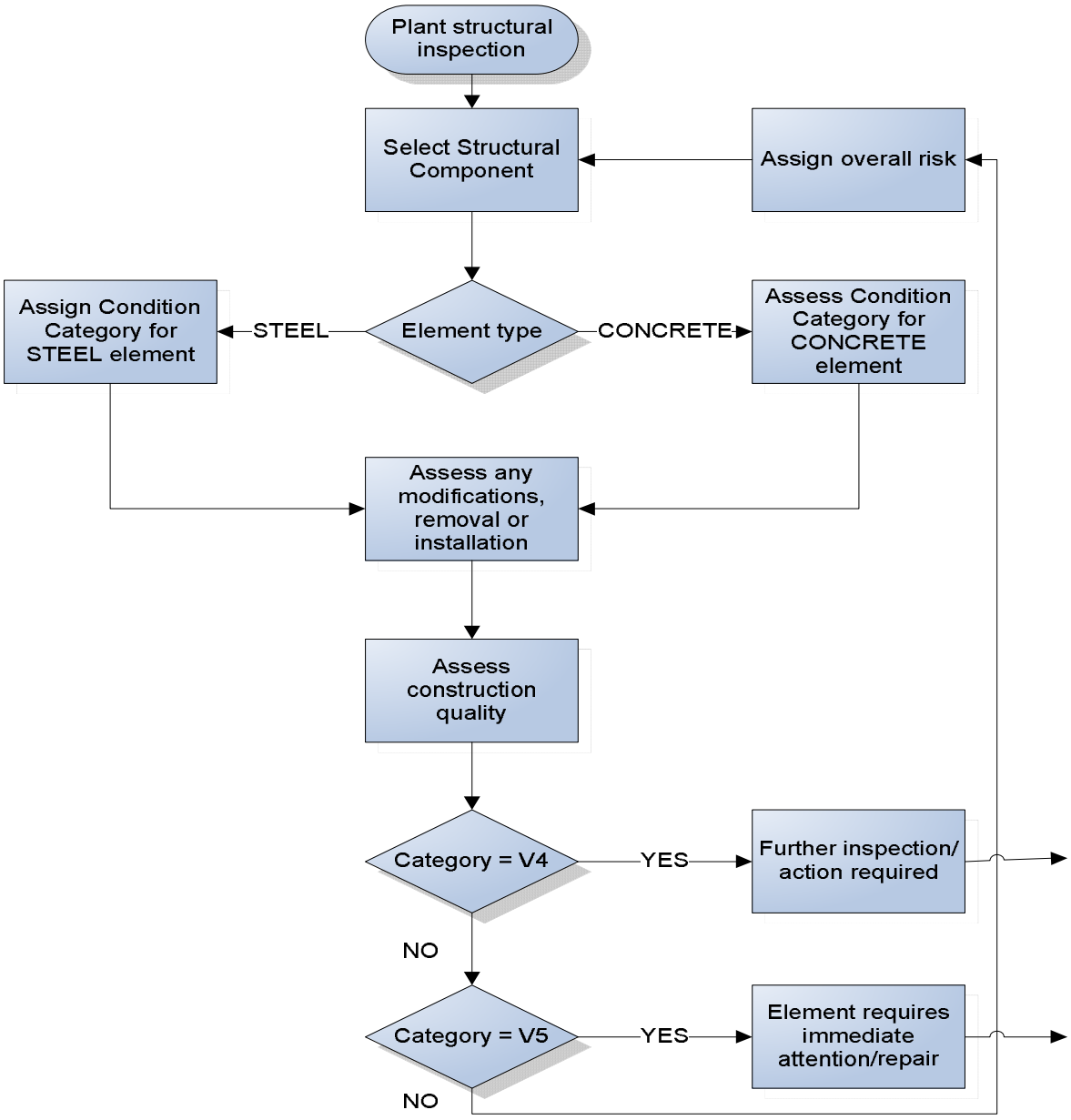
In the event that any Structural Elements are assigned a V4 or V5 Condition Category, the overall Condition Category of the relevant Structural Component is to also be either V4 or V5. A Structural Component may, however, be assigned a V4 or a V5 Condition Category even if none of its Structural Elements are assigned a V4 or a V5 Condition Category. An inspector may assess that the cumulative effect of matters identified in an inspection warrants V4 or V5 Condition Category for the Structural Component even if lower Condition Categories are assigned to any of its Structural Elements.

The inspection should be carried out by a suitably qualified engineer. However, this procedure may also be used by site personnel to carry out a rapid assessment of the integrity of a Plant Structure, in which case a Condition Category greater than V2 should be followed by an inspection by a suitably qualified engineer.

In some cases it may be necessary for an inspector to request that a Structural Element be cleaned prior to inspection. If so, the Structural Element should be inspected and

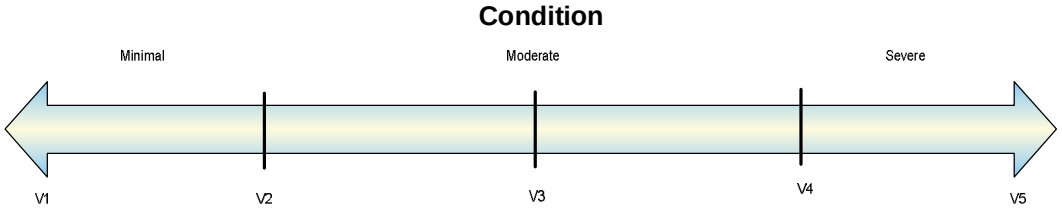
photographed before cleaning to record the typical operating condition which may give some indication of the cause of any deterioration in the structural integrity. Cleaning should use non-destructive techniques and grit blasting for example, should be avoided. It is recommended that an inspector carry a wire brush and welder's chipping hammer to assist with an inspection.

Inspection process



7.1 *Condition Categories*

The inspection is visual and the integrity of a Structural Element is classified into one of five categories ranging from V1 to V5 as shown below. Category V1 represents optimal condition typical of a new Structural Element. Category V5 represents a Structural Element in a condition that requires immediate action to be taken.



The "V" prefix represents that the classification is made on the basis of a visual appraisal with no thickness measurements or covermeter checks involved.

The basis for each of the five Condition Categories are:

V1 Near perfect.

V2 Minor deterioration evident but no immediate action required.

V3 Action required to arrest deterioration or correct defects.

V4 Based on a visual inspection, a structural defect is identified that may impair the structure's fitness for purpose and/or pose a safety risk.

Action required to investigate further, or take remedial action, or alter operations as required.

V5 Severe deterioration or failure potentially imminent.

Immediate alteration to operations required and immediate remedial action to be taken.

7.2 Output

Each inspection sheet (ENG-FRM-032) prepared should be scanned and entered into SiteSafe. Any actions arising from the inspection should also be entered into SiteSafe by the inspector (if a Boral employee), otherwise by the Site Manager.

8. Condition of Structural Elements

8.1 Reinforced concrete

Concrete degradation can be caused by such matters as chloride ingress, carbonation and in some cases alkali-silica reaction. If a concrete structure is subject to extended periods of excessive loads, fatigue and/or failure may occur.

Most high strength reinforced concrete is constructed using untreated reinforcement bars (rebar).

Cracking or spalling is normally the result of an inadequate quantity of rebar, or rebar spaced at too great a distance. Cracking allows moisture to enter the structure, exposing the rebar to further deterioration.

When rebar corrodes, the oxidation products expand and flake, cracking the concrete and unbonding the rebar from the concrete which may ultimately lead to structural failure. See Appendix A for examples.

Category	Observation
V1	No observed defects of any kind.
V2	Stains. Minor surface defects. Cracking (less than 0.5mm). Limited honeycombing but no sign of further deterioration.
V3	Local spalling. Lack of cover. Signs of corrosion to reinforcement. Cracking (greater than 0.5mm). Extensive honeycombing.
V4	Distress to member: deflection, crushing etc. Significant or widespread corrosion or spalling. Doubt regarding structural integrity.
V5	As V4, but failure of the member is judged to be potentially imminent.

8.2 Steel

The structural integrity of steel may be degraded by:

- Corrosion;
- Distortion/deflection;
- Bolt deterioration; and/or
- Excessive vibration.

An assessment against each of these matters is intended to ensure a comprehensive inspection.

8.2.1 Corrosion

Corrosion is the deterioration of the essential properties of a material due to reactions with its surroundings. In most cases this is due to constant exposure to air, water and oxygen.

Corrosion is the single greatest threat to the integrity of steel structures and is often the underlying catalyst for detrimental effects. Advanced corrosion has a negative effect on the strength of steel through the breakdown of intramolecular bonds.

Site environments that consist of constantly large quantities of surface liquid have a greater potential to cause the onset of corrosive effects. It is imperative that corrosive effects are halted before steel rigidity is compromised.

See Appendix B-1 for examples.

Category	Observation
V1	No corrosion. Protective paint intact. No signs of subsurface defects or previous repairs.
V2	Minor corrosion and/or localised pitting. Possible degradation of top layer of protective coating. Note: steelwork in this category, although now protected by an adequate paint system, may have corroded in the past and some loss of section may have occurred. Members which have suffered holed or noticeably thin sections will fall into

Category	Observation
	category V4 unless a comprehensive programme of thickness measurements is undertaken.
V3	Corroded. Top coating of protective paint is peeling and/or flaking. Paint system broken down or some areas unpainted (loose scale to measurable pits likely on steel surface). Structurally insignificant loss of section. Note: structurally insignificant loss of section is deemed to be section loss up to 15% of the gross section area provided that the section loss is evenly distributed. Steelwork in this category will require thorough cleaning down or shotblasting, followed by repainting to Boral specification ENG-SPE-002. The "15%" is based on visual assessment.
V4	Advanced corrosion. Paint system totally ineffective. Significant loss of section. Holing of member. Member distorted. Note: significant loss of section is deemed to be a loss of greater than 15% of the gross section area. Members reported as category V4 will require further investigation, repair, replacement or removal. The appropriate course of action should be recommended in the report. The "15%" is based on a visual assessment.
V5	As V4, but failure of the member is judged to be potentially imminent. Extensive corrosion (>75% of structure). Possible loss of support section.

8.2.2 Distortion/deflection

In order for supporting beams and trusses to withstand nominal loads correctly, it is imperative that all frame work be free from distortions and deflections. Even small areas of damage can significantly weaken the load bearing capability of supports.

In an industrial setting, distortional damage mainly arises from accidental contact by mobile equipment or by falling materials.

Beam failure due to distortion can be caused by a combination of factors including overloading and torque effects.

See Appendix B-2 for examples.

Category	Observation
V1	No damage.
V2	Minor damage.
V3	Section damaged in more than one area.
V4	Severely damaged or buckled.
V5	Section failure judged to be potentially imminent.

8.2.3 Bolt deterioration

In nearly all industrial constructions common anchor bolts are used to hold structural members in place.

Cross member supports also contain heavy duty bolts and nuts, which over time may become loose as a result of temperature fluctuations or corrosion.

It is imperative that these bolts and accompanying nuts are kept securely fastened so as not to allow any external sources of vibration to compromise the structural integrity of the supporting load.

See Appendix B-3 for examples.

Category	Observation
V1	All bolts accounted.
V2	All bolts accounted for, however some may have loose nuts.
V3	Missing bolts with no impact to structural integrity.
V4	Missing bolts affecting structural integrity of member.
V5	More than 25% of original bolts missing.

8.2.4 Excessive vibration

Constant stopping and starting of devices such as conveyors and vibrating screens exerts large dynamic forces. This is due to the velocity and acceleration required to move or slow them down.

The analysis of vibration effects can be contentious given the visual nature of this assessment. It should be noted however that excessive vibration of structural members is likely to be reasonably obvious.

Category	Observation
V1	Little or no vibration felt.
V2	Vibration localised around equipment.
V3	
V4	
V5	Components of element (eg nuts) vibrating loose. Vibration of element is visible.

8.3 Removal, modification or installation

Even though structures may show no outward signs of deterioration an assessment of the overall adequacy of supporting members is necessary.

It is possible that removal, modification or installation works or activities may have taken place over the years that have the potential to exacerbate the effects of environmental wear.

The inspection should seek to identify any of the following:

- Removal of cross beams to allow easier staff/machinery access;
- Drilling of webs of columns;
- Welding to heavily loaded columns (heat may lead to distortion and weakening of structure); and
- Addition of heavy structures (walkways, large steel wear plates, roofing etc).

See Appendix C for examples.

Category	Observation
V1	No instances of structural support removal, or addition of objectionable weight.
V2	
V3	Possible removal of supports or additional weight, however due to properties of structure there is no cause for concern.
V4	
V5	Removal of supporting structure which could impact affect structural integrity. Addition of large, un-engineered superstructure which has the potential to cause structural failure or affect original design integrity.

8.4 Design & construction

In general, the inspection should seek to identify design and construction details giving rise to a concern as to structural integrity.

See Appendix D for examples.

Category	Observation
V1	No instances of noticeably risky construction.
V2	
V3	
V4	
V5	Un-engineered construction, considered to be potential for risk.

Appendix A

Reinforced concrete condition categories: examples

V2

V3

V4

V5

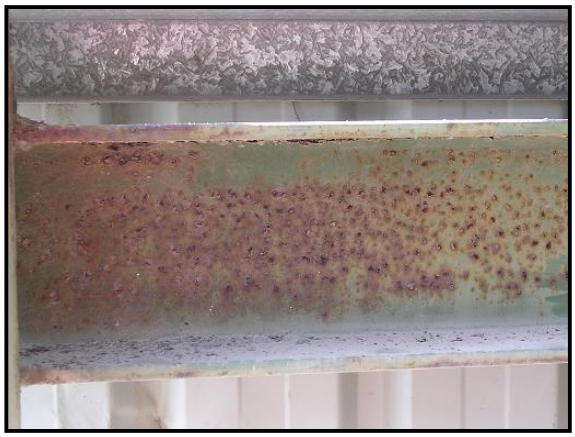
Category	Observation
V2	Stains. Minor surface defects. Cracking (less than 0.5mm).; Limited honeycombing but no sign of further deterioration.
V3	Local spalling. Lack of cover. Signs of corrosion to reinforcement. Cracking (greater than 0.5mm). Extensive honeycombing.
V4	Distress to member: deflection, crushing etc. Significant or widespread corrosion or spalling. Doubt regarding structural integrity.
V5	As V4, but failure of the member is judged to be potentially imminent.

Appendix B-1

Steel condition categories – corrosion: examples

V2

V3



V4

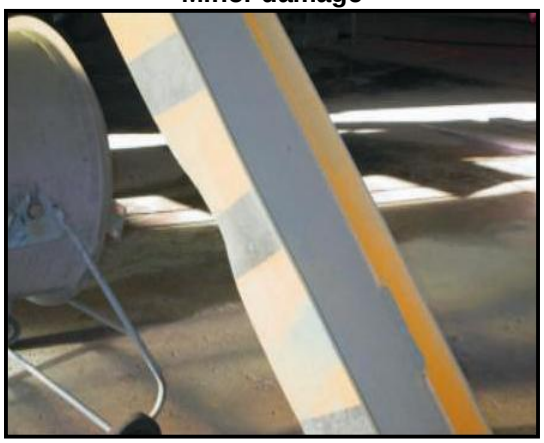
V5

Category	Observation
V2	Minor corrosion and/or localised pitting. Possible degradation of top layer of protective coating.
V3	Corroded. Top coating of protective paint is peeling and/or flaking. Paint system broken down or some areas unpainted (loose scale to measurable pits likely on steel surface). Structurally insignificant loss of section.
V4	Advanced corrosion. Paint system totally ineffective. Significant loss of section. Holing of member. Member distorted.
V5	As V4, but failure of the member is judged to be potentially imminent. Extensive corrosion (>75% of structure). Possible loss of support section.

Appendix B-2

Steel condition categories – distortion/deflection: examples

V2
Minor damage



V3
Section damaged in several areas

V4
Severely damaged

V5
Section completely missing

Category	Observation
V2	Minor damage.
V3	Section damaged in more than one area.
V4	Severely damaged or buckled.
V5	Section missing. Potential failure.

Appendix B-3

Steel condition categories – bolt deterioration: examples

V2

V3

V4

V5

Category	Observation
V2	All bolts accounted for however some may have loose nuts.
V3	Missing bolts with no impact to structural integrity.
V4	Missing bolts degrading safety factor of member.
V5	More than 25% of original bolts missing.

Appendix C

Removal, modification or installation: examples

V2

V3

V4

V5

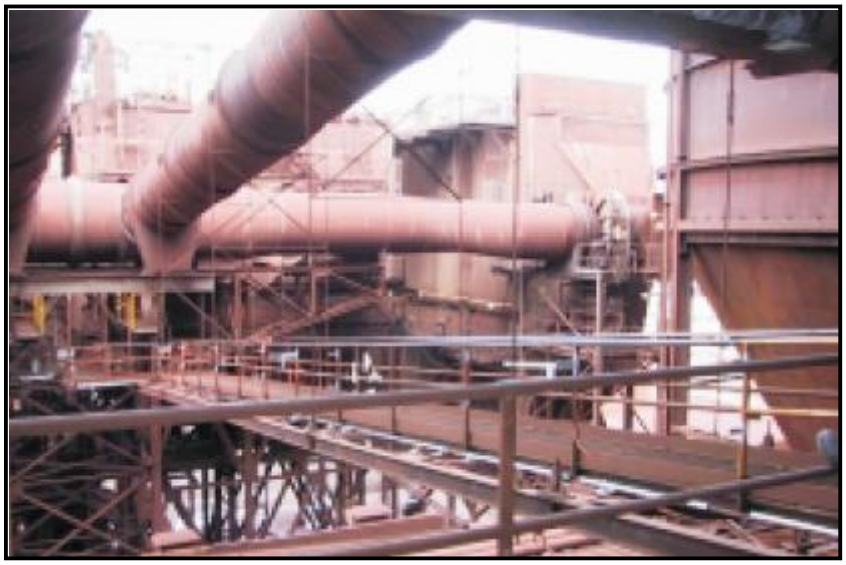
Category	Observation
V2	
V3	Possible removal of supports or additional weight, however due to properties of structure there is no cause for concern.
V4	
V5	Removal of supporting structure which could affect structural integrity Addition of large, un-engineered superstructure which has the potential to cause structural failure or affect design integrity.

Appendix D

Questionable construction: examples

Category V3: Boxed column. Why has a boxed column been fabricated? Has the column-beam connection been designed? Further investigation required.

Category V4: Beam cleats (connection between beams) of questionable design.



Category V3: Suspended walkway questionable. Needs further investigation.

Category	**Observation**
V1	No instances of noticeably risky constructions.
V2	
V3	
V4	
V5	Un-engineered construction, considered to be potential for risk.

Appendix E

It is imperative that the auditors pay particular attention to the following areas:

Concrete plant

The structures within concrete batching sites are exposed to high pH water. For the purposes of this audit it should be noted that the areas requiring the most attention include:

- Silo support which are exposed to highly alkaline liquid.
- Cross beam members and bolts.
- Shed roofs (batch offices, admixture bunds, loading bay etc) – check that there is no buildup on the roof.
- Stockpile retaining walls.

Quarries

Quarries also have naturally occurring issues which promote many of the factors that may lead to deterioration of structural integrity. The most common of these is fine dust particles produced through the crushing process, which when wet and left covering steel may damage the member's protection.

- Anchor bolts constantly covered in fine dust.
- Conveyor supports close to stockpiles.
- Retaining walls constructed of concrete blocks which may cause serious damage to structures if they fall.
- Conveyor tail and head areas – buildup of material.
- Material transfer points – buildup of materials.

Appendix F

Example completed inspection forms

Document Name:	**FORM FOR INSPECTION OF PLANT STRUCTURES**
Reference:	ENG-FRM-032 r1
Issue Date:	
Author(s)	
Authorised By:	
Distribution:	

This form should be completed in accordance with ENG-PRO-032

Site	Example 1	**Inspector**	
Date		**Company**	
Manager		**Signature**	

Structural Component	Silo Level 1 – SW corner top		
Picture taken	Yes / ~~No~~	**References**	Photo 1

Structural Element		**Category**	**Comments**
Concrete		N/A	
Steel	Corrosion	V2	Slightly corroded
	Distortion/deflection	V1	
	Bolt deterioration	V4	Nuts corroded severely. Requires further investigation.
Excessive vibration		V1	
Modifications		V1	
Design & construction		V1	
Worst Category		**V4**	**Bolt deterioration** **Hard to detect consequence of failure considering support is not load bearing.**
RISK ASSESSMENT RATING		**HIGH**	**36**

Categories V4 & V5 require further action

Action required

Bolts and nuts will need replacing. Bracing to be taken back to bare metal in area and painted. Structural engineer to approve work method statement as temporary removing wind bracing.

Photo 1

Document Name:	**FORM FOR INSPECTION OF PLANT STRUCTURES**
Reference:	ENG-FRM-032 r1
Issue Date:	
Author(s)	
Authorised By:	
Distribution:	

This form should be completed in accordance with ENG-PRO-032

Site	Example 2	**Inspector**	
Date		**Company**	
Manager		**Signature**	

Structural Component	Conveyor 4 – centre supports		
Picture taken	Yes / ~~No~~	**References**	Photo 2

Structural Element	**Category**	**Comments**
Concrete	N/A	
Steel Corrosion	V3	Slight corrosion with paint flaking
Distortion/deflection	V1	
Bolt deterioration	V1	
Excessive vibration	V1	
Modifications	V1	
Design & construction	V3	Support round has been affected by washout and may be undermining the supports rigidity.
Worst Category	**V3**	**Failure unlikely to occur but would result in a major incident**
RISK ASSESSMENT RATING	**MEDIUM**	**32**

Categories V4 & V5 require further action

Action required

Inspect foundations for settlement/movement.

Photo 2

Document Name:	**FORM FOR INSPECTION OF PLANT STRUCTURES**
Reference:	ENG-FRM-032 r1
Issue Date:	
Author(s)	
Authorised By:	
Distribution:	

This form should be completed in accordance with ENG-PRO-032

Site	Example 3	**Inspector**	
Date		**Company**	
Manager		**Signature**	

Structural Component	Conveyor 3 – centre support		
Picture taken	Yes / ~~No~~	**References**	Photo 3

Structural Element	**Category**	**Comments**
Concrete	N/A	
Steel Corrosion	V3	Slight corrosion. Minimal paint remaining.
Distortion/deflection	V4	Damage – FEL contact?
Bolt deterioration	V3	Bolts may have been weakened due to impact. Some missing.
Excessive vibration	V1	
Modifications	V1	
Design & construction	V1	
Worst Category	**V4**	**Possible failure. Potential to cause severe damage.**
RISK ASSESSMENT RATING	**HIGH**	**36**

Categories V4 & V5 require further action

Action required

Members to be replaced. Bollards to be installed to prevent continuing damage to structure.

Photo 3