

# Concrete Saw Cutting Incident

## Root Root Analysis

### Saw Blade Failure

Blade Segment Loss – Damage to Station Building

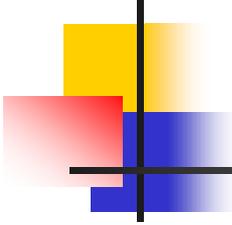


Active Service Station  
Ventura, California

Incident  
January, 2009



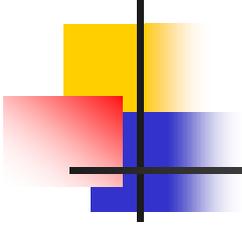
**Stantec**



# Incident Information

---

- Site Description
  - Active Service Station Facility
  - Self-Serve Gas, Convenience Mart, Car Wash
  
- Task Involved
  - Ozone Sparge System Installation
  - Saw Cutting Concrete for Piping Installation (Trenching)
  
- Severity of Incident
  - Impacts to Station Window Glass
  - Potential for Severe Injury

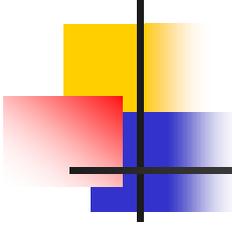


# Incident Overview and Investigation

---

- Purpose and Goals of Review
- Incident Summary & Investigation
  - ✓ **Site and Task Description**
  - ✓ **Incident Summary & Basic Facts**
  - ✓ **Diamond Blade Basics**
  - ✓ **Blade Type Investigation**
- Identify Potential Causes and Solutions
  - ✓ **Root Cause Factors (Tap Root)**
  - ✓ **Root Cause Analysis**
  - ✓ **Summary of Findings**
  - ✓ **Recommendations**
  - ✓ **References & Resources**

# Incident Summary and Investigation



Stantec's construction sub-contractor was saw-cutting through cured concrete prior to creating a trench to connect a new sparge well to a remediation system. A walk-behind concrete saw was being used. During the saw-cutting process, 23 diamond-impregnated saw blade segments broke off from the steel saw blade core.

A number of the broken segments did not stay within the saw blade's enveloping safety guard (shroud) or within the cut line. The segments ejected behind the saw at an angle, and impacted the station windows.

# Site Plan and Work Area Exclusion Zone



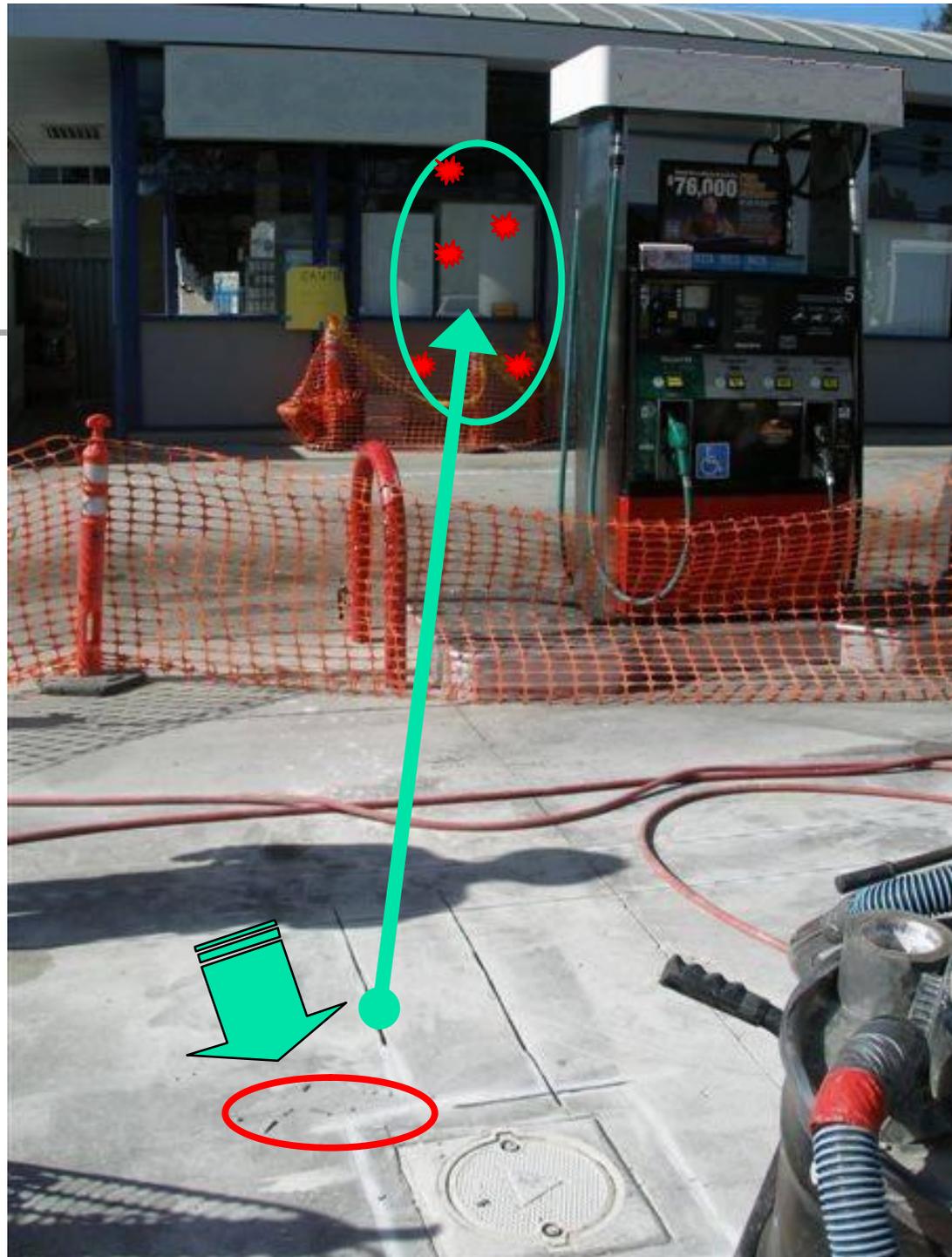
# Incident Summary

Concrete saw-cutting activities were being performed by the construction contractor on January 20, 2009 near new ozone sparge well CS-12 for trenching (within the exclusion zone between two dispenser islands east of the station building).



# Incident Summary

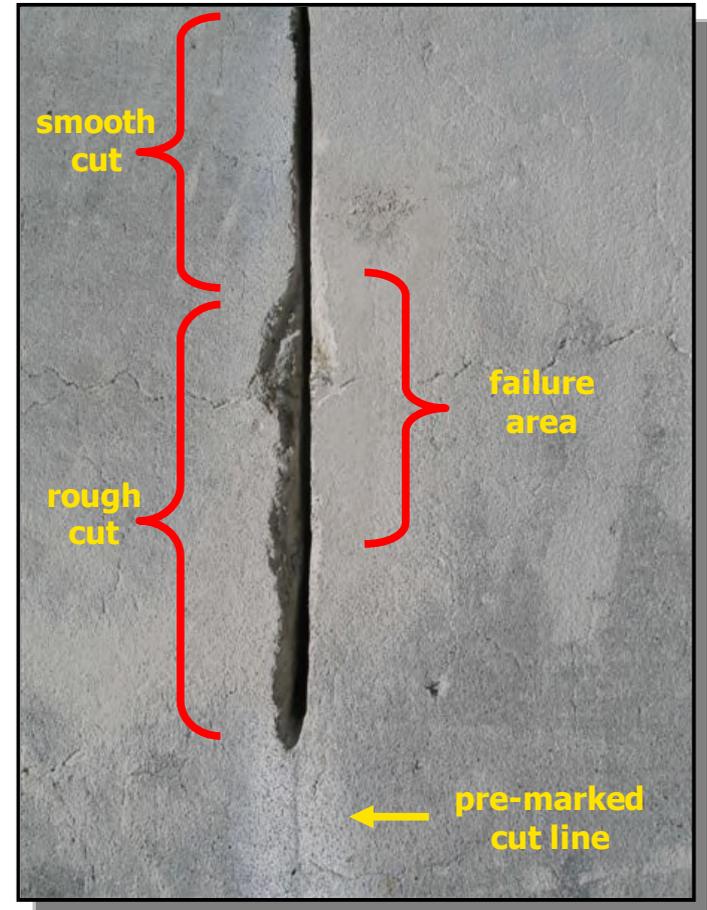
The saw was cutting toward the well box in the foreground and the lost cutting segments were ejected backward at an angle to the cutting plane, and impacted the building's windows in the background.



# Incident Summary



# Incident Summary



***23 of a total 27 segments broke on the saw blade***

# Incident Response



Stop work authority was invoked to evaluate damage, determine what occurred, and the cause of segment loss. It was determined that the broken blade segments had not stayed within the safety guard that envelopes the blade, and had ejected at an angle, impacting the station windows.

The impacted windows were secured with delineators and orange construction fencing to keep pedestrians away. A caution sign was placed on the impacted windows. Once the site was secured notifications were made to Stantec and client managers.

The Stantec Account, Program, and Project Manager immediately mobilized to the site to initiate the incident investigation.

# Incident Response

## ■ Corrective Actions (Next Day)

- New saw blade was installed.
- Wooden barriers were erected in front of and behind the saw to provide an additional safety barrier should additional segment loss/ejection occur.
- The impacted windows were removed and replaced.

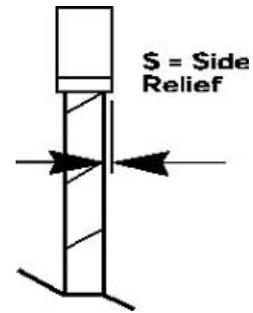


# Incident Summary – Basic Facts

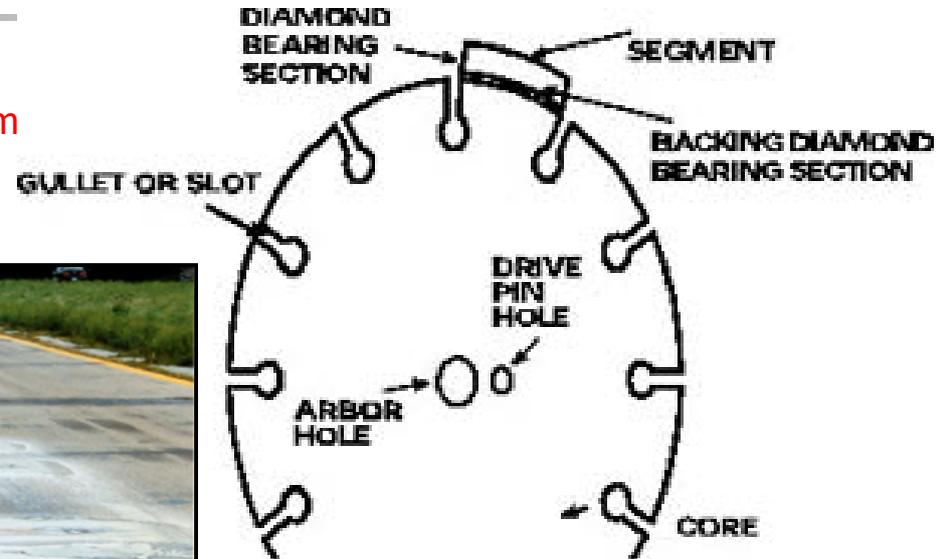
- The operator has five years of saw cutting experience.
- Masterpiece Engineering Company (MECO) 35 horsepower, self-propelled walk behind floor saw:
  - 18-inch diameter wet cutting diamond saw blade (mounted correctly).
  - Saw manufacturer states that 18-inch diameter blade would have approximately 2,800 rotations per minute when operated on saw.
- Coolant water was being used to cool the blade during cutting.
- Total target depth was approximately 4 inches bgs (each individual cut path did not exceed 2 inches in depth).
- Cut lines were marked on a string line with paint for the operator to follow.
- As the saw is designed, the safety guard does not completely cover the blade.



# Diamond Blade Basics



Photographs on this slide are examples only – not from the subject saw cutting incident at COP Site 5523



**Blade Rotation**



# Diamond Blade Basics

Diamond tools don't really "cut" like a knife... they grind.

The '**segments**' consist of diamonds in a metal matrix called a '**bond**'. The segments are attached to a steel blade or '**core**' by a laser weld or brazed weld. The segments are slightly wider than the core.

During the manufacturing process, individual diamond crystals are exposed on the outside edge and sides of the diamond segments or rim. These exposed surface diamonds do the grinding work. Trailing behind each exposed diamond is a "bond tail" which helps support the diamond under load. This extra metal holds the diamond crystal in the metal bond longer and is the reason that bond tail development in a cutting segment is so important for blade performance.

While the blade rotates on the arbor shaft of the saw, the operator or saw pushes the blade into the material. The blade begins to "cut" through the material, while the material begins wearing away the segments.

Exposed, surface diamonds score the material, grinding it into a fine powder. Embedded diamonds remain beneath the bond surface. Exposed diamonds crack or fracture as they cut, breaking down into even smaller pieces. Hard, dense materials cause the diamonds to fracture even faster. The material also begins to wear away the metal matrix through abrasion. Highly abrasive materials will cause the matrix to wear faster.

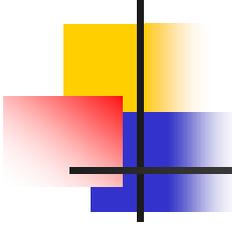
This grinding and wearing process continues until the blade segments are worn down. **It is important to understand that the diamond blade and the material must work together (or interact) for the blade to cut effectively.** The blade must be matched to the material to be cut. Some blades are rated as "**multi-purpose**" for cutting a wider range of materials.

In order for a diamond blade to work properly, the diamond type, quality, and grit size must be suited for the saw and the material. The metal matrix or bond must also be "matched" to the material. **Tools for cutting hard, dense (less abrasive) materials (such as tile, hard brick, stone or hard-cured concrete) require a softer metal matrix.** The softer metal matrix wears faster, replacing worn-out diamonds fast enough for the blade to keep cutting. **Tools for cutting soft, abrasive materials (such as block, green concrete or asphalt) must have a hard metal matrix to resist abrasion and 'hold' the diamonds longer.**

This grinding and wearing process continues until the blade segments are worn down. **It is important to understand that the diamond blade and the material must work together (or interact) for the blade to cut effectively.** The blade must be matched to the material to be cut. Some blades are rated as **"multi-purpose"** for cutting a wider range of materials

BLADE MODEL	Green Concrete	Asphalt	Abrasive Block	Concrete Block	Cured Concrete	Standard Brick	Hard Pavers	Ceramics	Soft Stone	Medium Hard Stone	Hard Stone
GES			GES		pg. 1						
SEG			SEG		pg. 1						
GPS			GPS		pg. 1						
SBL			SBL		pg. 2 & 12						
PSA	PSA		pg. 2 & 12								
PSG								PSG		pg. 2 & 14	
PDHS1			PDHS1		pg. 3						
PDHS2			PDHS2		pg. 3						
PDHS3			PDHS3		pg. 3						
SW2			SW2		pg. 4						
CHST								CHST		pg. 6 & 14	
HSC						HSC				pg. 7	
HSE						HSE				pg. 7	
PWBA	PWBA		pg. 22								





# Incident Summary – Blade Type Investigation

---

1. Stantec photo documented the incident scene and equipment extensively.
2. Stantec personnel requested the saw blade that was being used when the segment loss occurred.
3. The contractor provided the saw blade to Stantec.
4. Due to a lack of specifics from the contractor on the saw blade being used when segment loss occurred, Stantec conducted an investigation to determine the saw blade specifications including make and type.
5. Stantec cleaned the saw blade in effort of identifying any markings/labels on the blade.

# Incident Summary – Blade Type Investigation



Photograph of saw blade core after Stantec cleaned the saw blade

# Incident Summary – Blade Type Investigation

- Web search of numerous major saw blade manufacturers
- In person discussions with three local equipment/saw blade providers
- Email and telephone correspondence with saw blade manufacturers
- The initial investigation resulted in possibly identifying the saw blade manufacturer as Multiquip
- Stantec contacted Multiquip and provided the description and ID # observed on the saw blade
- Multiquip confirmed that the subject saw blade was a Multiquip manufactured saw blade
  - The 18 PRO-A (ID# 18768943) blade is no longer made but a new model identified as the 18PWBA has the same specifications.
  - The blade is designed to be used with a walk-behind saw with a horsepower range of 13 through 35
  - The diamond saw blade has laser-welded segments
  - The blade is designed for cutting asphalt and green concrete
  - The blade is not designed to and is not recommended for cutting cured concrete

# Incident Summary – Blade Type Investigation

## PWBC

Superior quality performance and operational life when cutting:

- Cured concrete

## PWBA

Superior quality performance and operational life when cutting:

- Asphalt and green concrete



WALK BEHIND  
(Medium HP)

## Premium Plus



DRY/WET  
CUT

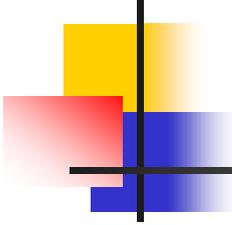
LASER  
WELDED

Model	Size	Arbor	List \$
12PWBC	12" x .125"	1"	\$275
14PWBC	14" x .125"	1"	\$340
16PWBC	16" x .125"	1"	\$395
18PWBC	18" x .125"	1"	\$435
20PWBC	20" x .125"	1"	\$465
Model	Size	Arbor	List \$
12PWBA	12" x .125"	1"	\$275
14PWBA	14" x .125"	1"	\$340
16PWBA	16" x .125"	1"	\$395
18PWBA	18" x .125"	1"	\$435
20PWBA	20" x .125"	1"	\$465



**MQ**  
MULTIQUIP

For Walk-Behind Saws 13HP  
to 35HP



# Root Cause Factors

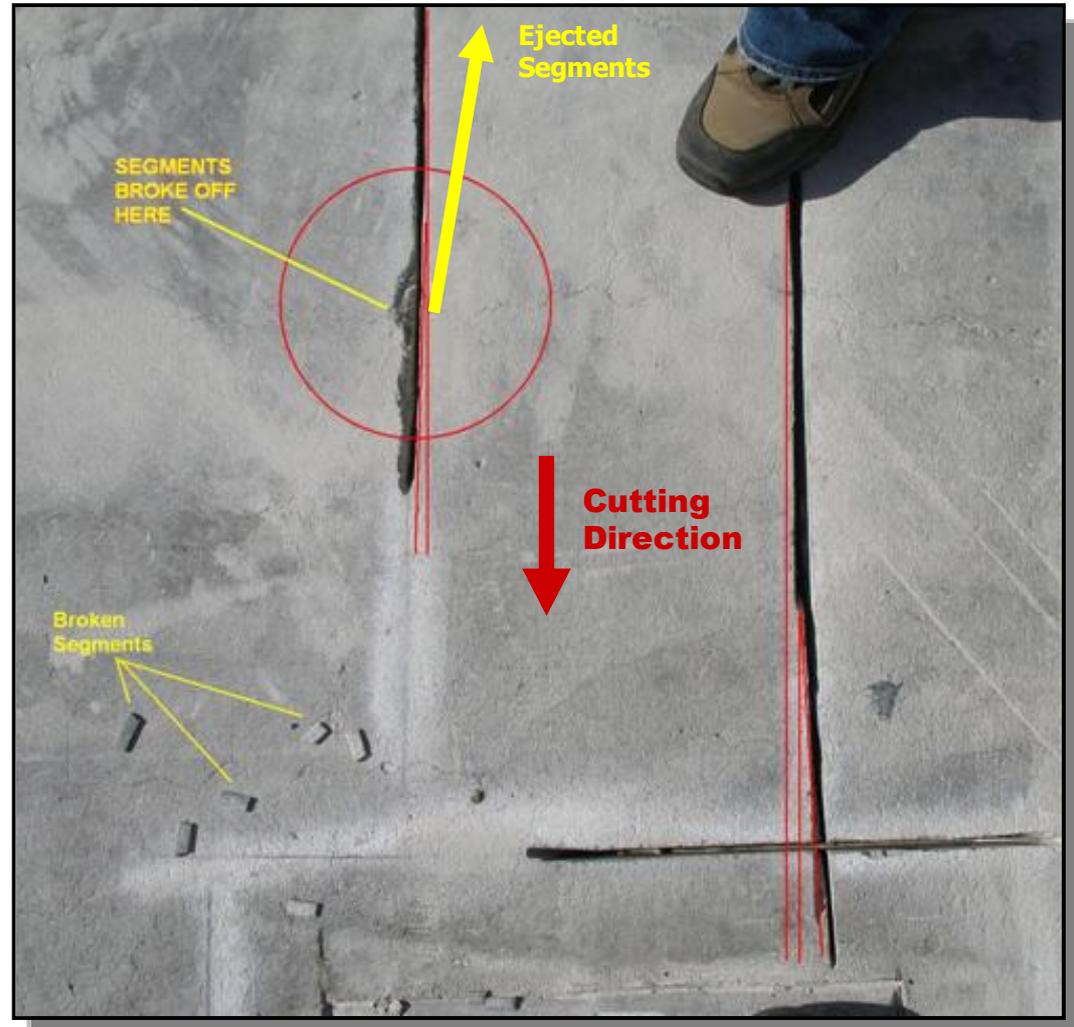
---

- **Human Performance Difficulty**
  - ✓ Individual Performance
  - ✓ Team Performance
  - ✓ Management System
- **Equipment Difficulty**
  - ✓ Design
  - ✓ Preventive/Predictive Maintenance
- Natural Disaster / Sabotage – N/A
- **Other**
  - ✓ Condition of concrete/rebar being cut – uncontrollable ???

# Basic Cause - Procedures

## Individual Performance

**Saw cut was not completed in a straight line thereby increasing friction and resistance on blade core and segments**

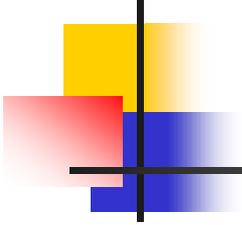


# Basic Cause - Procedures

## Individual Performance

- Material being cut was concrete; saw blade was designed to cut asphalt.
- Incorrect blade could have resulted in excessive wear of diamonds and undercutting of core.





# Basic Cause - **Communications**

## Team Performance

---

- Poor understanding/communication between the contractor's saw operator and Stantec's field representative about standard procedures for saw operation.
- Job Safety Analyses did not adequately identify and address potential saw cutting hazards.

# Basic Cause – Equipment Difficulty

## Design and Maintenance

### ■ Safety Guard (shroud) Size

- Different size guards are available based on the blade size. (14", 20", 24", 30"...)
- Some saws have adjustable guards or slip on guards.
- Guard helps keep water in the cutting area for cooling.
- "Mud Flap" at the rear of the guard controls water, slurry, debris from leaving the cutting area.
- Oversize guard may reduce visibility of operator to see the blade.
- Guards should be installed correctly per manufacturer specifications.



# Basic Cause – Equipment Difficulty

## Design and Maintenance

- The segments angle of ejection out of the plane of the saw blade suggest friction or lateral stress on the blade or the segments contacting the edge of the cut.
- Discoloration suggest possible wear from friction on the side of the blade which shouldn't occur when cutting in a straight line.
- The discoloration, possibly from lime or calcium build-up or staining could come from contact with the side of the cut.



# Root Cause Analysis Table

<p>Causal Factor #1 (Procedures / Equipment)</p>	<p>Causal Factor: Saw cut line curving to off line most likely increased friction on saw blade/segments</p> <p><b>Root Cause: Individual Performance/Equipment</b></p> <p>Solutions:</p> <ol style="list-style-type: none"> <li>1. Develop and implement procedures, checklist, SOPs to ensure the saw cuts are completed in straight lines.</li> <li>2. Check procedures for pre-marking saw cut lines, use spotter as necessary to remain on track, use the saw's guide wheel, check that machine is propelled in a straight line, use smaller diameter blade for first shallow cut pass.</li> </ol>
<p>Causal Factor #2 (Procedures)</p>	<p>Causal Factor: Saw operator or the blade may have made a sudden motion when being raised due to initial resistance</p> <p><b>Root Cause: Individual Performance/Procedures</b></p> <p>Solution: Perform saw cutting in slow, smooth, and even motions – <u>back saw out if binding</u> - avoid raising blade.</p>

# Root Cause Analysis Table

Causal  
Factor #3  
(Procedures)

Causal Factor: Use of improper saw blade (blade designed to cut asphalt was used to cut cured concrete)

**Root Cause: Individual Performance/Procedures**

Solutions:

1. Use saw blade designed for material to be cut.
2. Develop SOP for saw operation that includes selecting appropriate blade type for materials being cut.
3. Implement pre-operation procedures (e.g., checklist, tracking blade type) to verify that the correct blade is used.

Causal  
Factor #4  
(System)

Causal Factor: Lack of communication about standard operating procedures and potential hazards

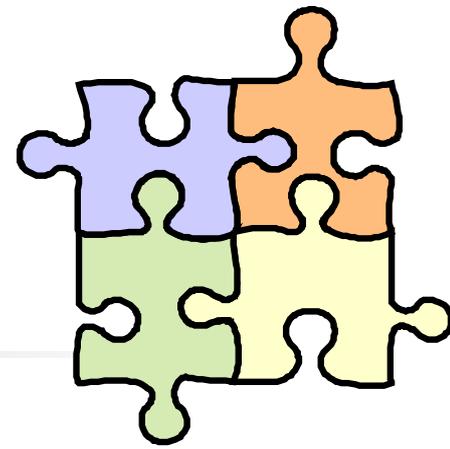
**Root Cause: Team Performance/Communications**

Solution: Ensure standard operating procedures are discussed and incorporated into job safety analysis and oversight personnel are experienced in hazards recognition for the task. 27

# Root Cause Analysis Table

<p>Causal Factor #5 (Equipment)</p>	<p>Causal Factor: Blade enveloping safety guard did not prevent broken segments from being ejected from cut line/saw.</p> <p><b>Root Cause: N/A - Determined not to be a cause</b></p> <p>Note: Confirm the safety guard size and the blade diameter are within manufactures specifications for the saw.</p> <p>Keep saw blade within the cut – use back-out procedure.</p> <p>In high traffic, public locations, expand exclusion zones and erect barriers in front of and behind the saw to provide an additional safety barrier should segment loss/ejection occur.</p>
<p>Causal Factor #6 (Other)</p>	<p>Causal Factor: Presence of unsupported rebar (below slab) may have caused vibration of rebar against saw blade segments resulting in loosening of segments.</p> <p><b>Root Cause: N/A - Determined not to be a cause</b></p> <p>Note: See Factor #3 – Correct blade needed for cured concrete with rebar reinforcement.</p>

# Summary of Findings



1. Cut lines were pre-marked on concrete in straight lines.
2. Operator was cutting the shallow 2" pre-cut with an 18" blade.
3. The concrete cut line where the failure occurred was curving to the right.
4. Operator was raising the blade due to increasing friction (binding) when failure occurred. There is no indication the motion to raise the blade was abrupt or sudden, but the release of tension on the blade may have been.
5. Rebar in the concrete near the point of failure was found to be between 3" to 4" below surface. Due to the shallow cut, rebar is not believed to be a factor in the blade failure as was first hypothesized in the field.
6. Cutting segments were laser welded to the blade's core, which is a stronger bond than brazed or soldered welds.
7. Contractor indicated they typically use a multi-purpose blade that is designed to cut concrete or asphalt.
8. The blade type was designed for asphalt and not cured concrete and was not a multi-purpose blade.

# Recommendations

## Equipment Procurement



- Most Desirable
  - Use a saw cutting/coring subcontractor who specializes only in concrete and asphalt cutting. Subcontractor owns and maintains their own equipment.
  
- Desirable
  - General contractor owns and maintains their own saw cutting and coring equipment, as well as provides other services and field operations. If the scope is beyond the capability of equipment, a subcontractor should be obtained.
  
- Not Desirable
  - Avoid using rental equipment where the contractor has little to no control over the specification, condition, and maintenance of the saws and blades.

# Recommendations Hazard Recognition (1)



## **Future Actions to Minimize Potential Re-Occurrence**

1. Develop saw cutting hazard recognition and pre-operation safety checklist for oversight personnel and contractors and incorporate the checklist into health and safety plans for projects that involve saw cutting operations.
2. Expand JSAs for trenching and saw cutting operations based on lessons learned from subject incident.
3. Only use saw blades specifically designed for the material being cut.
4. Evaluate the use of multi-purpose blades (at a minimum follow manufacturer's recommendations).
5. Evaluate changing blade types when material being cut changes.

# Recommendations

## Hazard Recognition (2)



### **Future Actions to Minimize Potential Re-Occurrence**

6. Consider use of smaller diameter blades for shallow, first pass cuts. Smaller diameter blades have less flex and help facilitate straight cuts.
7. Let the blade do the "cutting". Do not force the saw. If binding, friction, or resistance increases on the blade – back the blade out through the existing cut before raising or shutting off the blade.
8. Ensure Standard Operating Procedures (specific to the equipment) are obtained or developed and adhered to during equipment operation.
9. Evaluate adjustable safety guards and sizing the guard to the blade diameter – ensure that manufactures specifications are followed.
10. In public or high traffic areas, erect barriers in front of and behind the saw to provide an additional safety measure and expand exclusion zones (provides added safety containment in the event broken segments are not captured within the cut or safety guard).

# Recommendations Stantec Processes



- Incorporate **Hazard Recognition and Control (HRAC)** procedures into pre-work processes and a field checklist for saw cutting that ascertains and confirms that saw specifications, blade type, material to be cut, and planned cut lines are compatible and appropriate for planned site work.
- Stantec must obtain contractor's JSA's, SOP's and maintenance records before field work begins and review in detail using the above **HRAC procedures** for saw cutting.
- Update Stantec's **Trenching JSA** to include specifics for concrete cutting job steps, hazard recognition, PPE, and mitigating actions.
- Update Stantec's stand alone **Saw Cutting JSA** to include and address previously unrecognized hazards.

# Recommendations

## Saw Blades



- Contractors systematically index and track blade use
  - Blades can lose their labels and markings with use and a system should be in place to verify the blade specification and historic use (lineal feet).
- Utilize standardized industry codes to index blades if possible
- SMI/CSDA Blade Application Code for Diamond Saw Blades
  - The Masonry and Concrete Saw Manufacturers Institute (SMI), a product-specific group of the Association of Equipment Manufacturers (AEM), in conjunction with the Concrete Sawing and Drilling Association (CSDA), has developed a voluntary application code for diamond saw blades to help end users differentiate product capabilities and applications (2002-2004).
  - Not all saw blade manufacturers may use this system.
- Minimum the index/code should indicate:
  - Wet or Dry Blade
  - General Application: Asphalt, Cured Concrete, Masonry
  - Saw Type
  - Blade's previous use history

# References & Resources



## Professional Organizations & Regulations:

- Concrete Sawing and Drilling Association (**CSDA**), [www.csda.org](http://www.csda.org)
- Association of Equipment Manufacturers (**AEM**), Masonry and Concrete Saw Manufacturers Institute (**SMI**), [www.aem.org/CBC/ProdSpec/SMI/index.asp](http://www.aem.org/CBC/ProdSpec/SMI/index.asp)
- **OSHA – 29CFR, Abrasive Wheel Machinery.** - 1910.215, [www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=9839](http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9839)

## Articles Online:

- **Safety with Saws**, *Source: CONCRETE CONSTRUCTION MAGAZINE (online)*, [www.concreteconstruction.net/industry-ews.asp?sectionID=707&articleID=473727](http://www.concreteconstruction.net/industry-ews.asp?sectionID=707&articleID=473727)
- **All About Diamond Blades**, [www.ukdiamondtools.co.uk/acatalog/All\\_about\\_diamond\\_blades\\_and\\_cores.html](http://www.ukdiamondtools.co.uk/acatalog/All_about_diamond_blades_and_cores.html)

## Supplemental Information (See the next slide):

- Blade Application Codes – Voluntary (AEM-SMI/CSDA)
- Diamonds Don't Wear... Or Should They?, Patrick O'Brien, Director, CSDA 2002.
- CSDA Training Brochure 2009
- CA State Compensation Insurance Fund – Concrete and Masonry Saws
- AEM - Best Practices for Safer Concrete Cutting on Work Site