

Structural Strengthening of Concrete Structures

Truncation of Post-Tensioned Tendons

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21st May 2014

Today's Presentation

- What are tendon truncations?
- When should truncations be used?
- Why should truncations be used?
- PTIA recommended truncation procedures

***Where is the development length of a
post-tensioned tendon defined in
AS3600 ???***

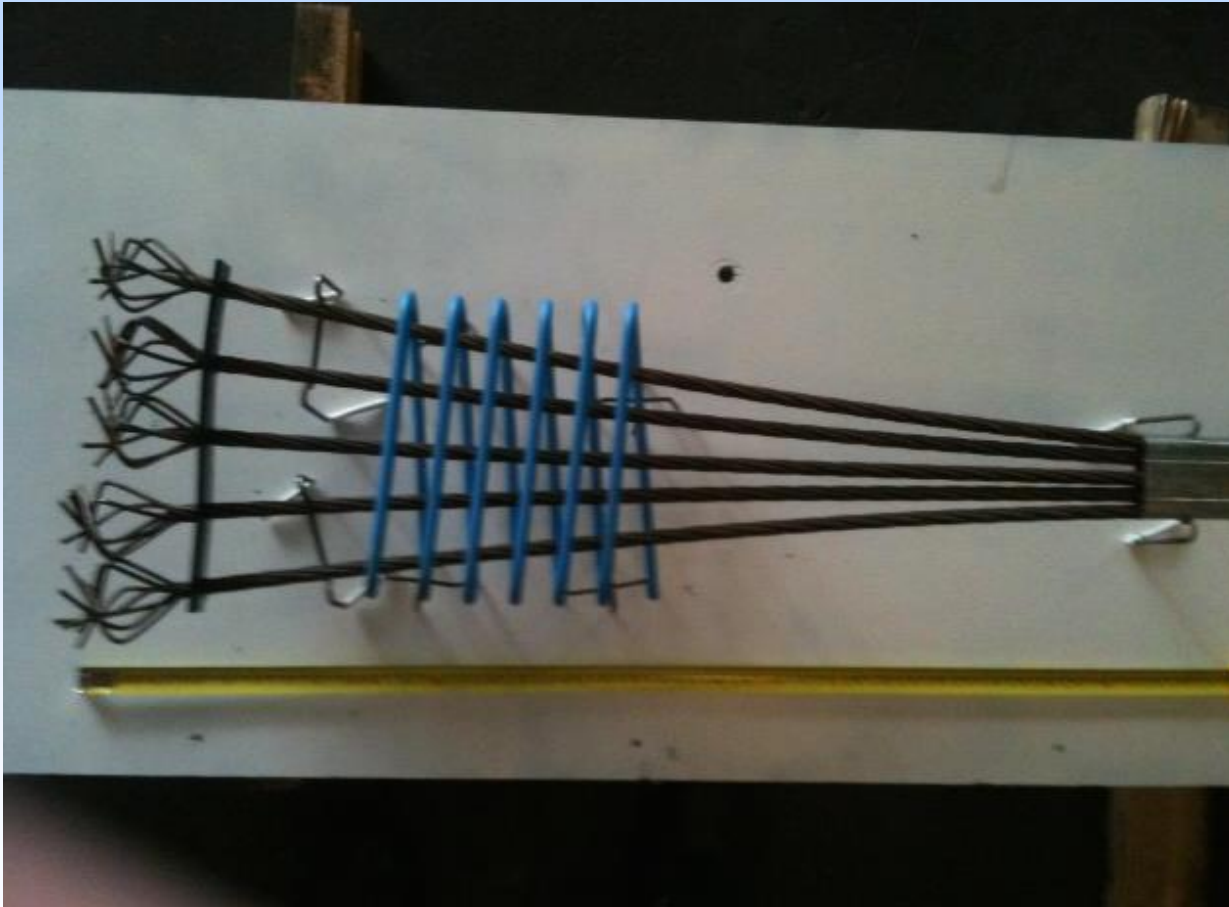
It isn't....

Post-tensioned tendons are always fully anchored by proprietary anchorage's.

Live End Anchorage



Dead End Anchorage



What are Tendon Truncations?

“A newly formed, epoxy based, anchorage zone in an existing post-tensioning tendon”

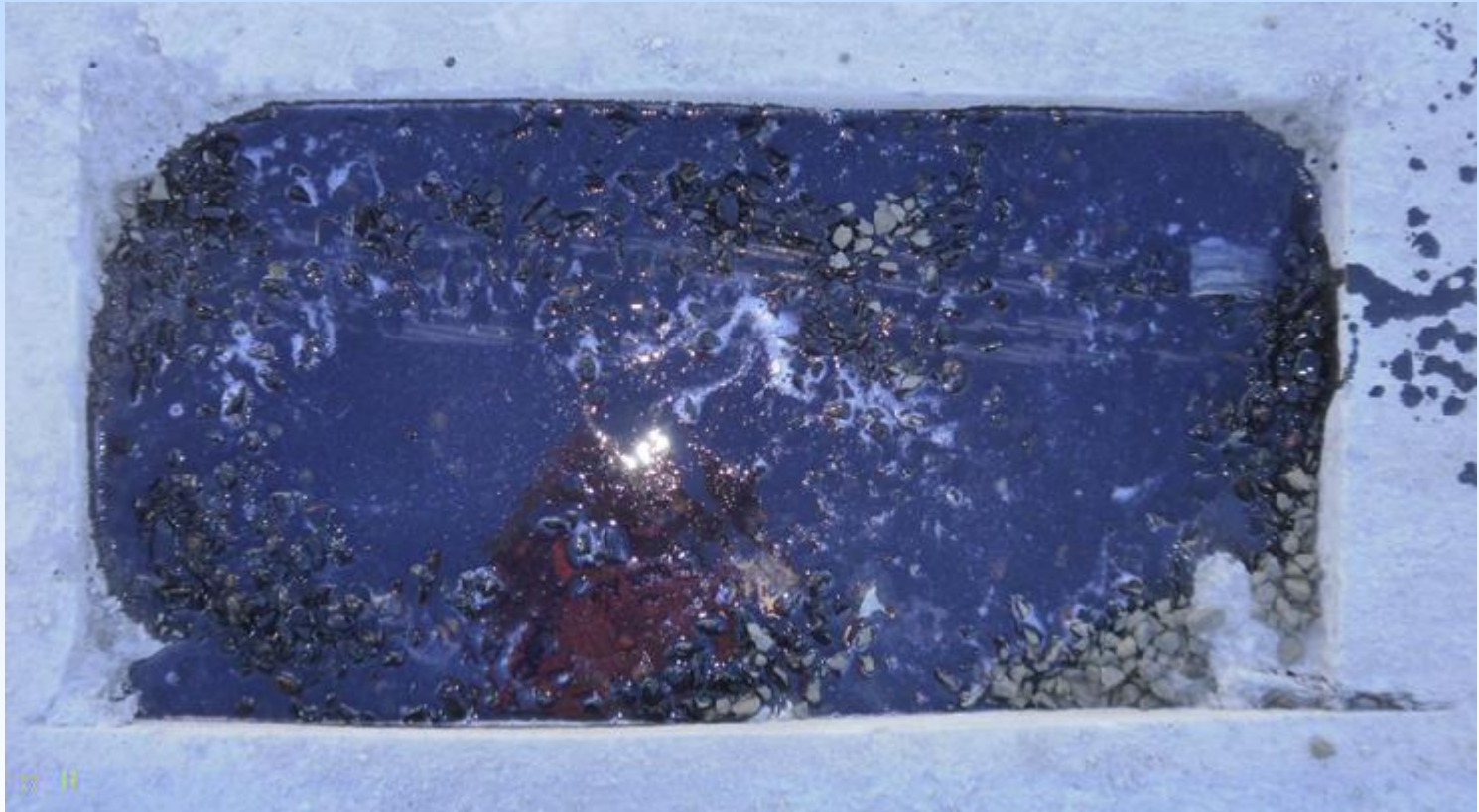
The anchorage zone is strengthened to achieve **comparable performance** to that of a proprietary cast in place anchorage system.

AS3600-2009 Cl. 13.3.3

“Anchorage for tendons shall be capable of developing the tendon the minimum tensile strength (f_{pb})”

Truncations should enable compliance with the intent of the code.

What are Tendon Truncations?



When should truncations be used?

PTIA promote the use of tendon truncations whenever the tendon is to be preserved.

It is appropriate to consider that the only tendons that do not require truncations are those that become redundant following the structural modifications, often due to insufficient lengths or substantially different load paths.

Post formed holes

Most tendon truncations are driven by a requirement for post-formed holes in post-tensioned slabs:

- **Large openings** for stair penetrations, service shafts etc in retrofit applications
- **Smaller penetrations** generally for mechanical requirements

Often larger holes, and those with limited tolerance for lateral positioning, intersect existing post-tensioned tendons.

Cores can often be detailed to avoid clashes with tendons.

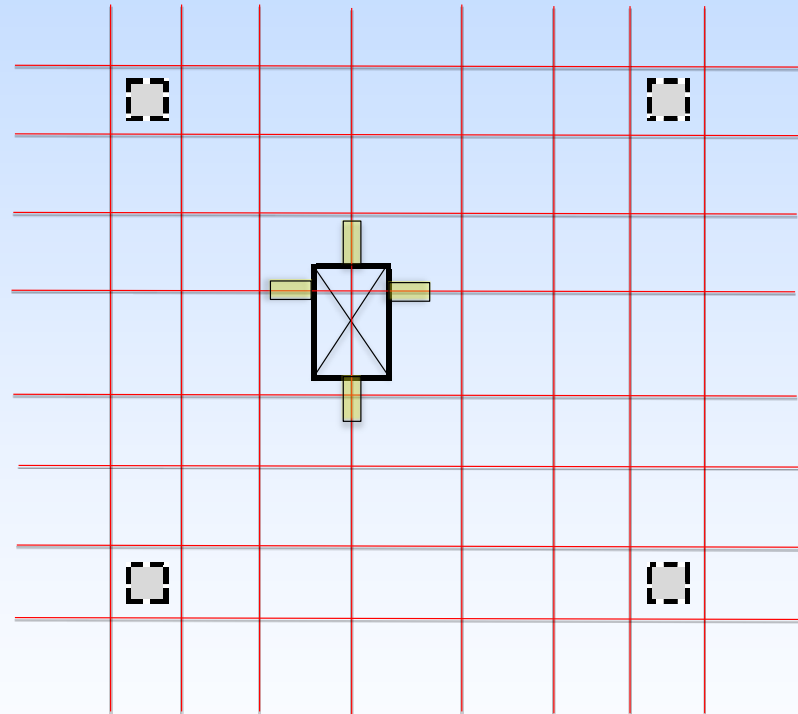
Detail smaller penetrations to prevent the need to truncate tendons whenever possible.

Truncations in two way slabs

Middle Strip / Middle Strip.

Generally low PT and reinforcement intensity.

Often surplus capacity available in positive moment Regions.

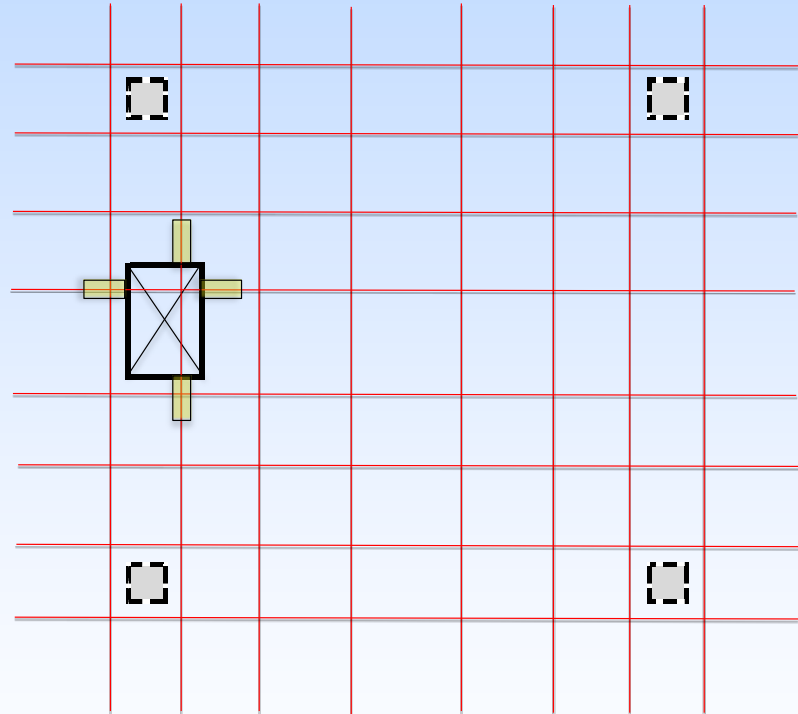


Truncations in two way slabs

Two Way Slabs

Column Strip / Middle Strip

Generally higher PT and reinforcement intensity in column strips.



Truncations in two way slabs

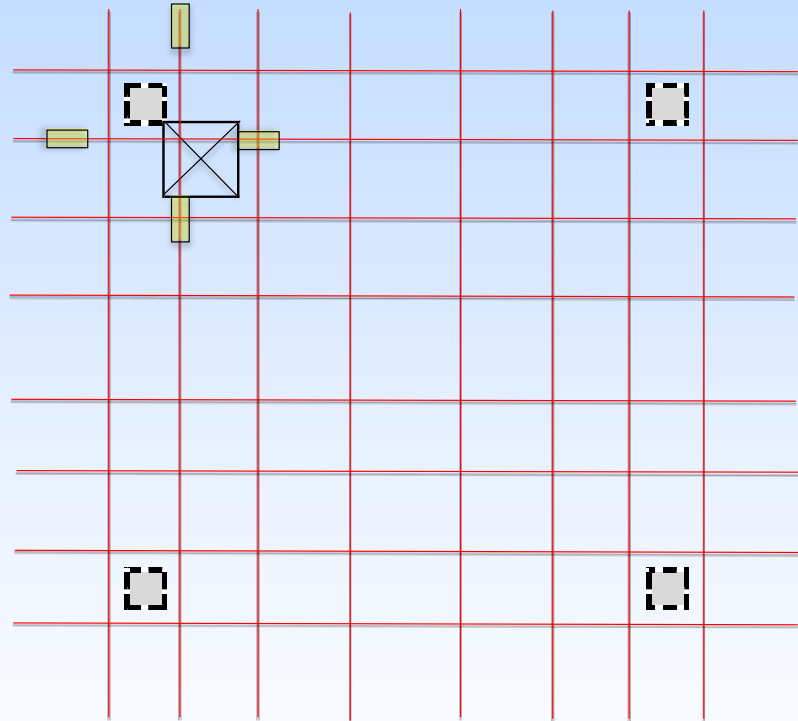
Two Way Slabs

Column Strip / Column Strip

Avoid where possible!

Highest PT and
reinforcement intensity.

Extreme care required to
maintain both flexural and
(punching) shear capacity.



Truncations in **one way** slabs / bands

Slab areas

Low intensity of PT and reinforcement

Bands / Beams

High PT and reinforcement intensity

Coring holes in beams is best avoided if at all possible due to the congestion of PT and reinforcement and little chance of alternate load paths.

Well placed and detailed soft zones in new structures can minimize the need for tendon truncation and other remedial works.

What about tendon grout?

Firstly, it is very important to understand the **role of grout in a post-tensioned tendon.**

Let's review the load transfer requirements of grout and the concept of **residual stress.**

For compliance with AS3600-2009 Cl. 8.1.7, in relation to strength provisions, the assumption is that at any time,

“ the minimum effective stress in the tendons is
not less than $0.5 f_{pb}$..”

Furthermore, at the time the tendon grouting occurs, the effective stress in the tendon will be more, say $\sim 0.6 f_{pb}$.

What about tendon grout?

Therefore the actual load transferred by the grout
will be less, $\sim 0.4 f_{pb}$

To achieve proof (yield) stress, much less again, say $\sim 0.3 f_{pb}$

Tendon grout was never intended / required to transfer the full load in the tendon – as would need to be the case if a truncation was not employed.

What about tendon grout?

Secondly, is the tendon FULLY grouted?

How is this to be guaranteed?

Visual inspection?

Past grouting practices over the years have not always been as reliable as present day processes.

Grout in one location on a tendon does not guarantee the quality, or even presence, of **grout in ALL locations**.

What about tendon grout?

Factors effecting grout performance:

Tendon blockage's

Blockage's can occur when grouting post-tensioning tendons.

This generally occurs when the duct seam fails, or, when the ducts are pulled apart by unforeseen displacement during concreting.

Blockages **should** be rectified immediately, but without specific quality control processes in place there is potential for un-grouted zones to be present.

What about tendon grout?

Factors effecting grout performance:

Bleed

Excessive bleed manifests itself as voids at tendon highpoints, resulting in poor bond transfer at the most highly stressed portion of the tendon.

Poor grout quality is never acceptable in post-tensioned concrete construction. However, a fully un-grouted tendon will only generally lose a portion of its ultimate strength, say ~25%, as long as it is anchored, ie. it remains tensioned.

An un-anchored, poorly grouted tendon may have close to zero capacity.

What about tendon grout?

Un-Grouted Tendons

If any un-grouted tendons are discovered, it is important to highlight the issue to the structural consultant.

Remedial grouting techniques are available to minimize the impact on fixtures and finishing's.

Such remediation may need to extended to beyond the tendons being truncated!

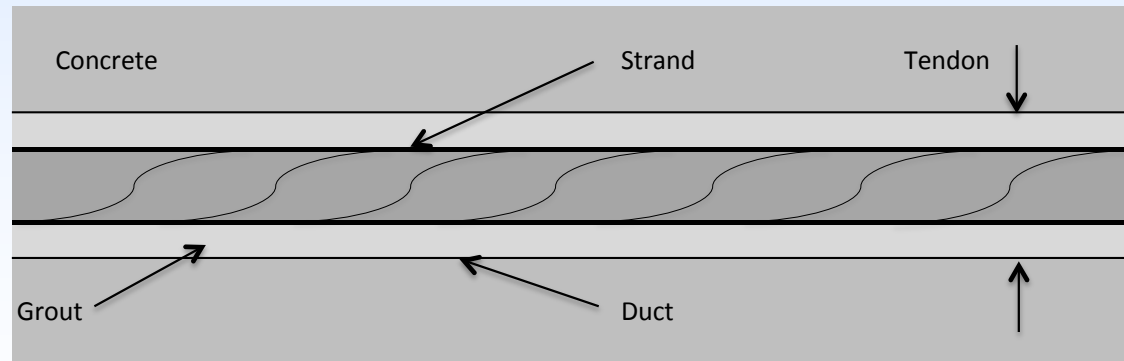


What about tendon grout?

Bond Strength

The bond strength of the strand to the concrete, in relation to a post-tensioned tendon will be limited by one, or a combination of, the following criteria:

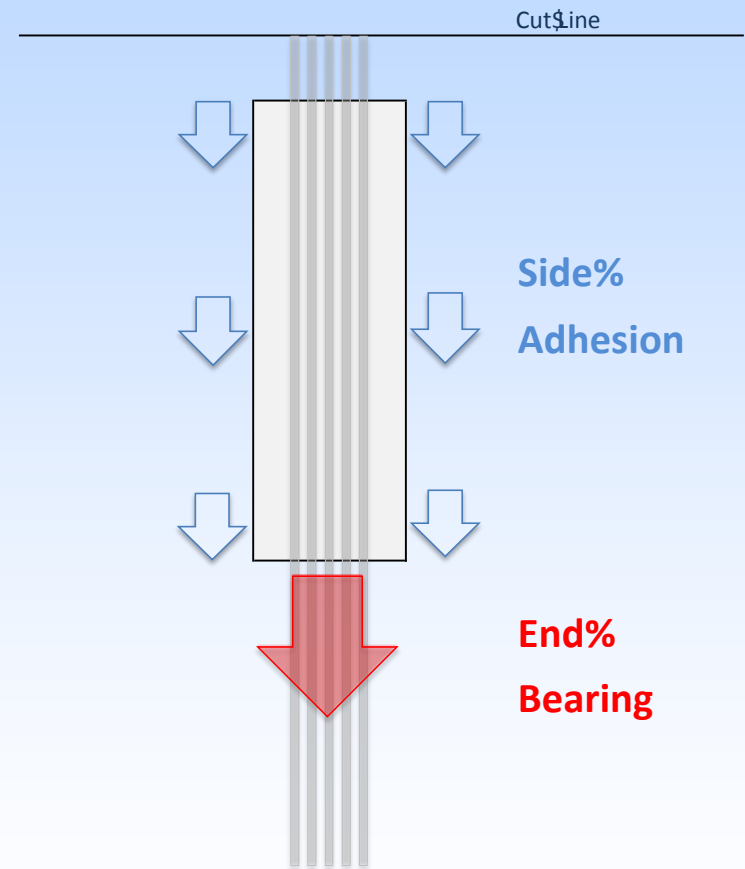
- *Strand to Grout*
- *Grout to Duct*
- *Duct to Concrete*



What about bursting reinforcement?

Truncations can be thought of as transferring load by both side adhesion and end bearing.

The epoxy bond to the side faces should have sufficient adhesion to allow the end bearing load to be within the range as defined by AS3600-2009 Cl. 12.6 to alleviate the need for special confining reinforcement.



Tendon truncations

PTIA recommendations

**No specific code coverage or guidance,
practices in industry vary.**

The below advice is quite generic, it may not be suitable for your specific application, refer to a PTIA member company for further details.

1. Safety First

Is all in-slab power completely disconnected?

Engineers – Safety in Design!

Check this appears on your documents.

We recommend that this is a formal sign of requirement.

Tendon truncations

PTIA recommendations

2. Is any necessary propping / supporting structure in position?

Ensure adequate propping is in position prior to commencement.

Consider the requirements of the **completed structure AND** the **temporary cases** that may occur during concrete removal – and as a result of concrete removal. Also consider the potential of damage to existing tendons during concrete removal.

Do not design propping to occur in areas that may need to be formed during the truncation process.

Tendon truncations

PTIA recommendations

3. Locate post-tensioning tendon positions

Depending on the structure, as-built drawings may or may not be available.

We recommend GPR scanning, by a suitably experienced operator, to ensure accurate identification of all tendons.

In addition, evidence of tendons on site can also be gathered from structure itself by suitably experienced personnel.

- Tendon staples
- Anchorage patches
- Pan recesses
- Grout hoses

Tendon truncations

PTIA recommendations

4. Concrete removal

Sawcut the perimeter of the hole to around 10mm depth prevent over break on the surface, this also avoids feathered edges.

Using large capacity jack hammers remove the concrete until the duct is visible or if the tendon depth is known, restrict large hammer to within say 10-20mm of the duct.



Tendon truncations

PTIA recommendations

4. Concrete removal

Never cut reinforcement without approval

No matter how tempting!!

Highly reinforced areas are also symptomatic of highly stressed, more sensitive areas of the structure.



Tendon truncations

PTIA recommendations

4. Concrete removal

Lighter capacity hammers can be used to remove concrete around the tendon, without damaging the strand itself. Ensure minimum clearances around the strand are achieved.

Take care when removing duct from the tendon, the cut material can be very sharp!



Tendon truncations

PTIA recommendations

5. Infill Material

Why epoxy? Can I use a very high strength micro-concrete?

Generally.... No.

Epoxy typically has compressive strengths of the order of 100MPa. However, there are some high performance micro-concretes now available that achieve similar compressive strengths – the issue here is two-fold:

- a) **Strength gain:** Normally truncations are required to be cut within a day or two of the installation, and,
- b) **Tensile / Bond Strength:** Epoxies generally exhibit **FAR** higher tensile / bond strength than cementitious products

Tendon truncations

PTIA recommendations

5. Infill Material

Epoxy should be chosen for their hardened performance criteria, and very importantly, their ability to be placed to the required placement depth.

Epoxy reacts and cures exothermically, producing high levels of heat – never exceed the manufacturers recommendations on placement depths.

PTIA preferred epoxy performance criteria,

Compressive strength:

60MPa in 24 hours (at the time of cutting)

100MPa in 7 days.

Tendon truncations

PTIA recommendations

6. Placement of Epoxy

Whilst all manufacturers recommendations must be followed, the most common error at site level is, part kit mixing and incorrect proportioning.

Incorrect mix proportions can result in epoxies that turn to jelly and take days / weeks to cure if at all, or, react so fast that they self fracture.

Once the epoxy has been place to the required depth, say 80mm – 100mm, central about the strand, broadcast course sand or fine aggregate to promote bond to the topping compound.

Tendon truncations

PTIA recommendations

7. Making good

Topping compounds, generally cementitious, should be selected to achieve performance criteria appropriate for the location.

Vehicular, forklift access, external, architectural etc.

Allow minimum 24hours curing time prior to saw-cutting tendon.

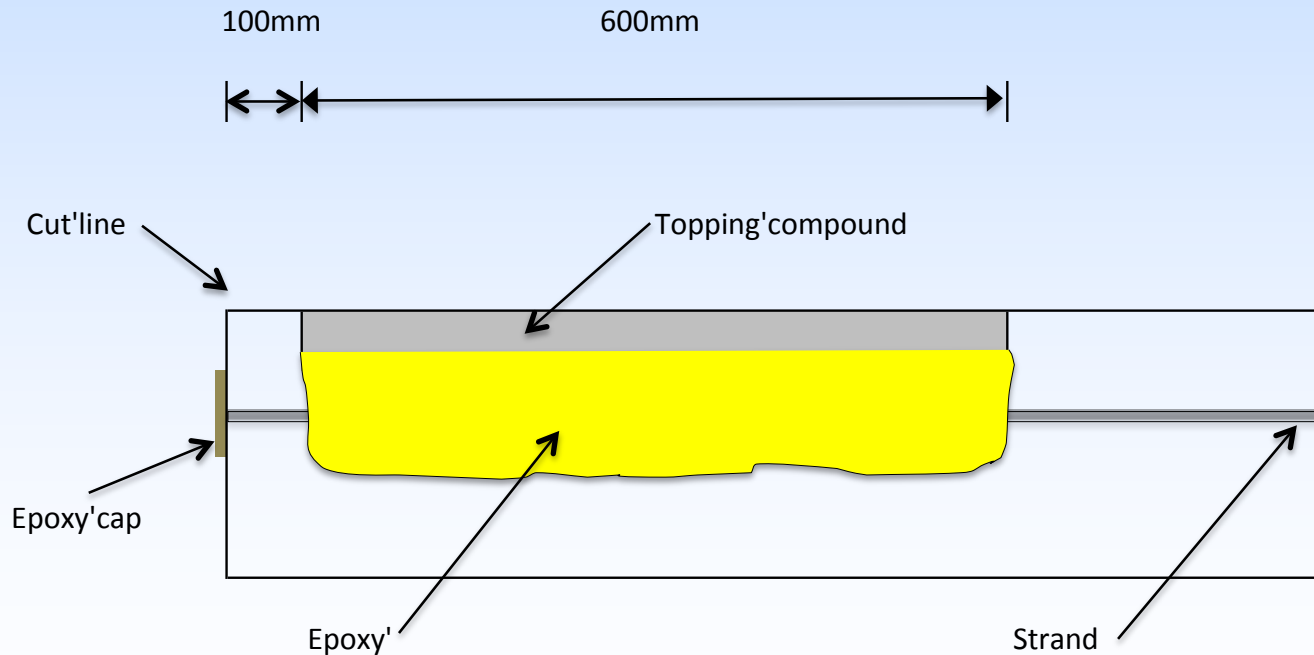
Strand ends should be epoxy coated at the cut face.

Tendon truncations

PTIA recommendations

Basic Completed Truncation

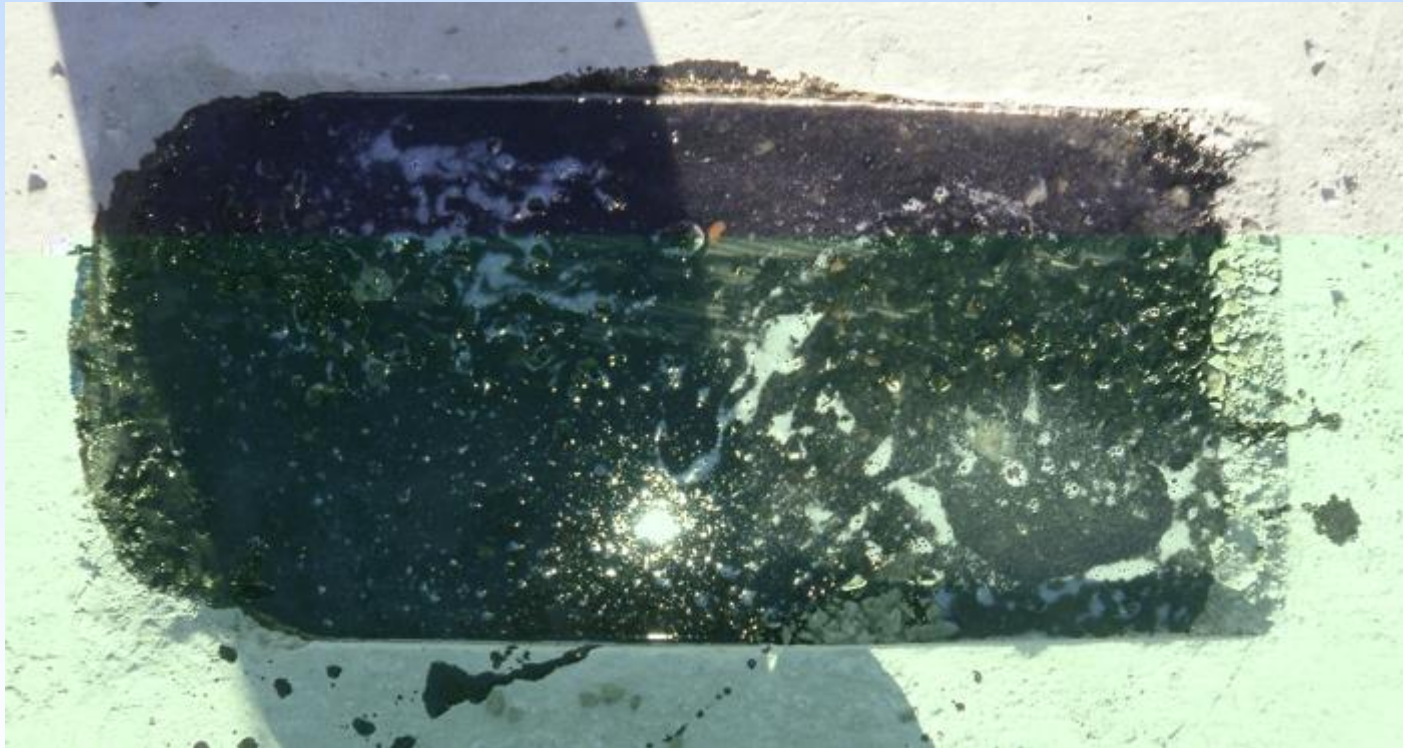
Nominal size: 600mm long x 250mm wide



Tendon truncations

PTIA recommendations

Basic Completed Truncation



Tendon truncations PTIA recommendations

New truncations, ready for penetration removal



Special Cases

Thin slabs / low tendon truncations

Tend to “break through” the soffit when removing concrete.

Ensure floor space under allows for debris collection and re-forming.

Saw-cut slab soffit to 10mm after concrete removal at perimeter.

If the strand to soffit cover is excessive, provide a cementitious self leveling grout bed to reduce the depth of epoxy under strand to within 35mm.

If epoxy must be placed directly onto formwork ensure appropriate debonding agents, eg plastic sheet or proprietary debonding waxes are used on formwork.

*** Epoxies have essentially zero resistance to fire ***

Special Cases

Slabs on Ground

Post-tensioned slabs on ground must remain completely isolated from all points of **restraint** – including the sub-grade.

If any “break through” occurs during the installation of the truncations, provide a self leveling grout bed on the sand / plastic to seal the hole prior to placement of epoxy infill.

Allow grout to cure for 24hrs prior to placement of epoxy, or, as directed by the epoxy manufacturers instructions.

Special Cases

Deep Sections

Truncations in deep sections, with low tendons, are best avoided where possible.

Take care when assessing slab / beam capacities and propping requirements during installation.

Ensure infill material is acceptable for in service performance.



Anchorage Proximity Restrictions?

We are often asked about how close to an anchorage can a truncation be formed.

This often occurs when slabs are formed out of tolerance.

If de-stressing can still occur and the tendons can be reset – ie. if the tendons are not grouted or cut off, this is the preferred option.

If grouting has already occurred, truncations will be required.

In the rare event that the defect is noticed after the tendons have been cut and sealed, but not yet grouted – other options are available.

Anchorage Proximity Restrictions?

Post-tensioning anchors transfer VERY large forces.

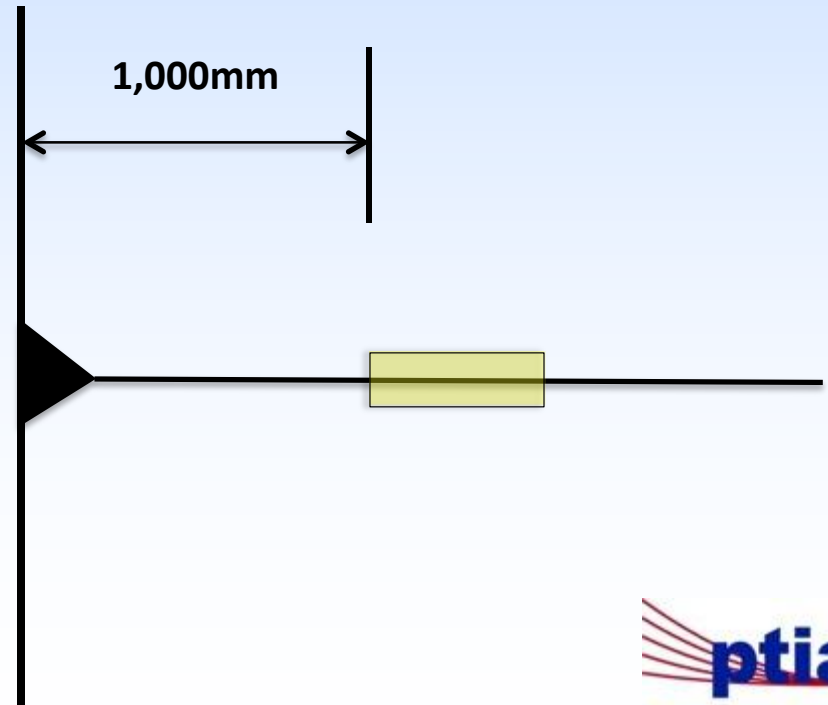
Never disturb concrete in anchorage zones!

All distances shown are absolute minimums, consult a PTIA member for site specific details.

Live Ends (Up to 5x12.7mm)

Maintain a minimum distance of 1,000mm from the start of the truncation to the face of the anchorage

The combined effect of adjacent anchorage's may require additional clearance.

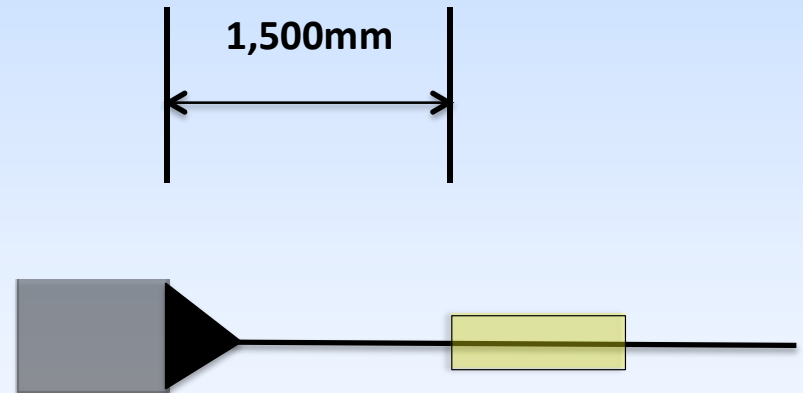


Anchorage Proximity Restrictions?

Pan Live Ends (Up to 5x12.7mm)

Maintain a minimum distance of 1,500mm from the start of the truncation to the face of the Anchorage.

It is good practice to visually inspect the grout hose for the presence of good grout, prior to commencing the work in the vicinity of any anchorage type

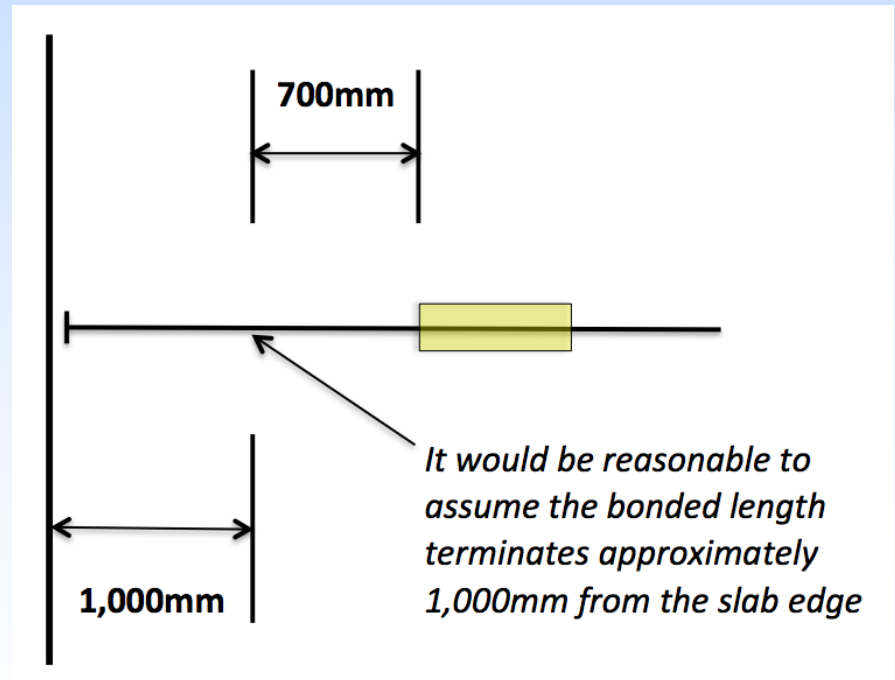


Anchorage Proximity Restrictions?

“Onioned” Dead Ends (Up to 5x12.7mm)

Maintain a minimum distance of 700mm from the start of the truncation to the start of the bonded length.

The “exclusion” zones noted are for both the vibration of the demolition and the void created for the truncation.



Oops... I've hit a tendon!

Inevitably, situations arrive where tendons are inadvertently cut before a truncation is provided, often during coring operations.

Partial Severance

Experienced core drill operators generally identify when they hit a post-tensioned tendon, which may result in partial severance only.

Often a core drill bit will effect only an edge strand or hit the top of the strands themselves. Each strand is comprised of 7 wires, in many cases partial capacity may be available.



Oops... I've hit a tendon!

Partial severance may not require a truncation if the partial capacity can be justified in a design review.

Full Severance

a) **Cuts where prestress loss is measurable**

Cores, sawcuts, etc.

b) **Cuts where prestress loss is unknown**

Mechanically broken or disturbed concrete

A truncation should be installed at a distance from the cut point so as to minimize the chance of further slippage during mechanical concrete removal. In case a) above, it is useful to monitor for any prestress loss.

Refer to a PTIA member company for further advice.

Builder / Developer

Consideration for Logistics...

Noise & Vibration

Dust

Out of hours work required??

Floors below – Access if concrete removal penetrates slab??

Isolation of in slab power and other services

Timeframe highly dependent on the nature of the truncation

Always allow for a minimum 24hour curing period, ~ 60MPa.

Summary

- Tendon truncations, performed correctly, allow for **surety** in design.
- Tendon performance may be guaranteed for the life of the structure.
- Relatively simple and economical to install.

PTIA member companies can assist with the design and execution of tendon truncations.

THANK YOU