

ADSC-IAFD Position Paper: Joints in Soil Nail Walls

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Introduction

Currently there is inconsistency within the design and construction communities regarding the usage of concrete joints for temporary and permanent shotcrete facings in soil nail walls. The typical ACI standards for crack control in cast-in-place concrete walls and slabs on grade do not adequately model shotcrete faced soil nail walls for the following reasons:

1. Each soil nail connection to the shotcrete face restrains the concrete from temperature or shrinkage movement. There is not an accepted analytical model that can properly identify the restraint induced by soil nail connections, and therefore, the temperature or shrinkage cracks cannot be determined or controlled.
2. The ACI standards regarding control or expansion joint locations in walls apply to an assumed uniform thickness of concrete that is placed in forms. Due to typically uneven surfaces behind the shotcrete wall, particularly on hard ground or rock faces, the thickness of the shotcrete can vary greatly.
3. In hard ground or rock faces, the shotcrete will bond to and interlock with the uneven jagged surfaces restraining the shotcrete in ways that cannot be quantified. The random distribution of stresses caused by this phenomenon generates cracks that cannot be predicted or controlled.

This paper presents the view of the ADSC-IAFD with regard to crack control practices with soil nail walls.

Background

Many designers compare soil nail wall facings to cast-in-place (CIP) concrete walls and rely on the provisions of ACI for reinforcement ratios and detail the construction as they would for free standing walls or slabs-on-grade (SOG)

The design of soil nail wall facings is based on yield line theory for two-way structural slabs supported on columns. As a result these elements act differently than one-way CIP walls and SOG.

Soil nail walls are generally constructed with a temporary facing and a permanent facing. The temporary facing is usually 4 to 5 inches thick with reinforcement ratios based on gross section ranging from .0016 to .004 and the permanent facing is generally 8 to 12 inches thick with reinforcement ratios ranging from .0018 to .003.

These values fall within the ACI 318 provisions for shrinkage and temperature reinforcement that require a minimum reinforcement ratio between .0014 and .0020.

ACI 318 explicitly states that these provisions are for structural slabs and not for SOG.

Soil nail walls are similar to SOG in that they are both cast against a soil surface, but two distinctions must be observed. The soil surface for SOG is a controlled and compacted surface whereas the surface for the soil nail is undulating and rough. The second difference to note when comparing SOG joints to

soil nail wall joints is that SOG joint types and spacing are based on unreinforced slabs, however soil nail walls are reinforced elements.

There are three types of joints commonly used in concrete construction: Construction Joints, Contraction Joints also called Control Joints, and Expansion Joints.

Construction Joints

Construction joints are used between sections of monolithic placement, typically to allow the work to be stopped for the day. In soil nail walls there is a horizontal construction joint used between lifts and a vertical construction joint used at the end of the day's work. The horizontal joint should be formed with a flat surface to allow the upper layer of concrete to bear on the lower lift.

Vertical construction joints can be constructed by angling the shotcrete toward the soil face at a 45° from the surface as shown below.

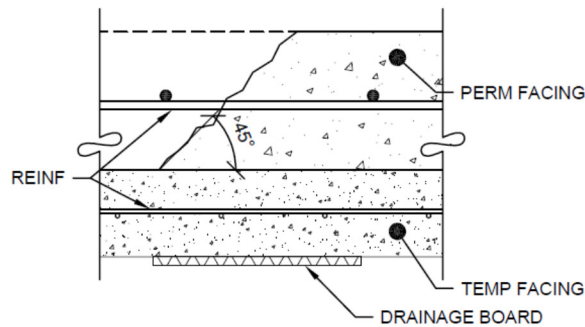


Fig 1 – Construction Joint Detail

Another method is to form the vertical joint by sandwiching the reinforcement between two pieces of lumber. The reinforcement should be continuous through all construction joints. Fig 2 depicts details for a typical horizontal construction joint in a temporary shotcrete facing. Photo 1 shows an example of this detail prior to shotcrete application as well as showing formwork in place for a vertical construction joint.

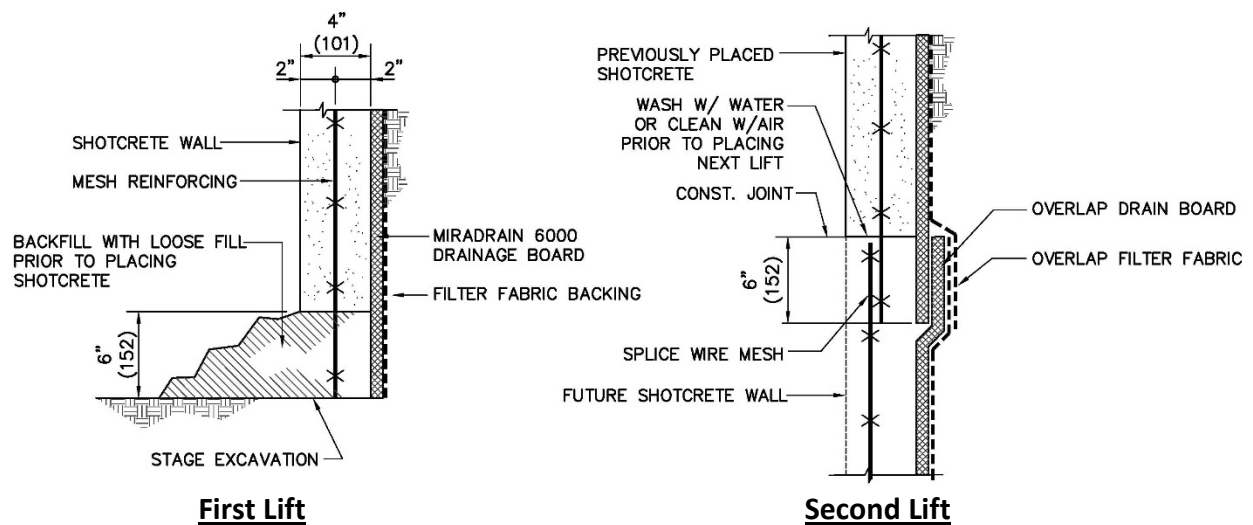


Fig 2 – Horizontal Construction Joint Detail

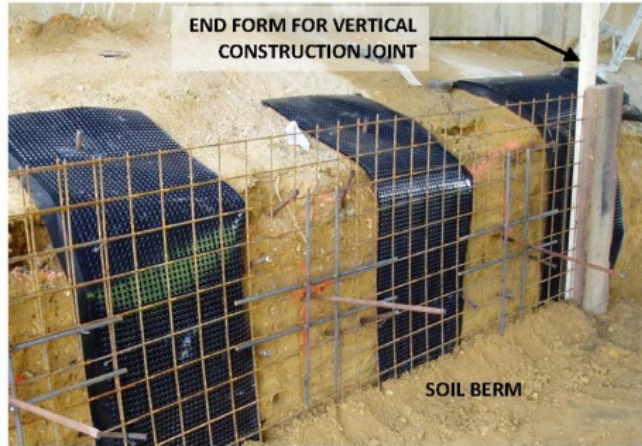


Photo 1 – Preparation of Horizontal and Vertical Construction Joints

Contraction Joints

Contraction Joints are used to control concrete cracking. Concrete cracks due to drying shrinkage and thermal changes. Contraction joints create a weakened plane by cutting or forming a groove into the concrete and reducing the thickness with the intention of having the cracks form at the opposite side of the groove.

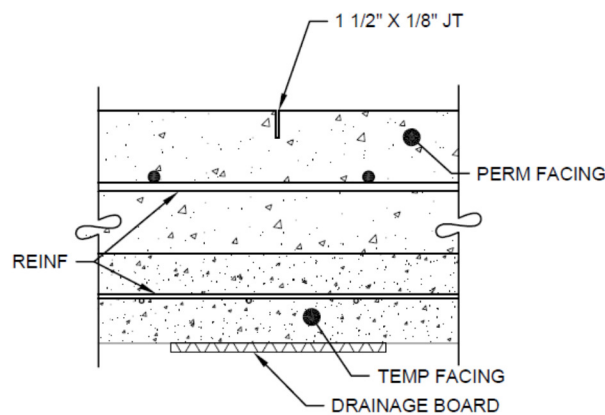


Fig 3 – Contraction Joint Detail

Frequently designers specify contraction joints at 45' on center in the permanent facing and no contraction joints in the temporary facing.

If the reinforcement meets the ACI ratios for shrinkage and temperature and is adequate for strength, it is the view of the ADSC-IAFD is that adherence to ACI standards with respect to both expansion joints and contraction joints when used in soil nail walls does not necessarily prevent cracks from appearing and as such these joints are not required in soil nail wall facings, both permanent and temporary. However, there may be conditions where their use is still advisable. For example, on exterior right-angled soil nail walls, some contractors incorporate a contraction joint at the end of the soil nails on the perpendicular face (See Photo 2)



Photo 2 – Contraction Joint in Right-Angle Soil Nail Wall

Soil nail walls can be constructed with a sculpted facing to appear as natural rock and blend in with the surrounding features. Control joints in sculpted facings ruin the natural appearance. As a result there has been plenty of experience with the performance of soil nail walls with a sculpted facing. One project, prepared for the State of California in 2009, had 197,000 square feet of sculpted facing without contraction joints or expansion joints and varied to wall heights up to 96' of exposure. This wall (Photo 3) does not exhibit signs of cracking.



Photo 3 – Sculpted Wall Facing without Joints

Other experience has shown on a non-sculpted face wall installed with contraction joints, the drainage board created a slip plane and cracks appeared at each drainage board location regardless of their

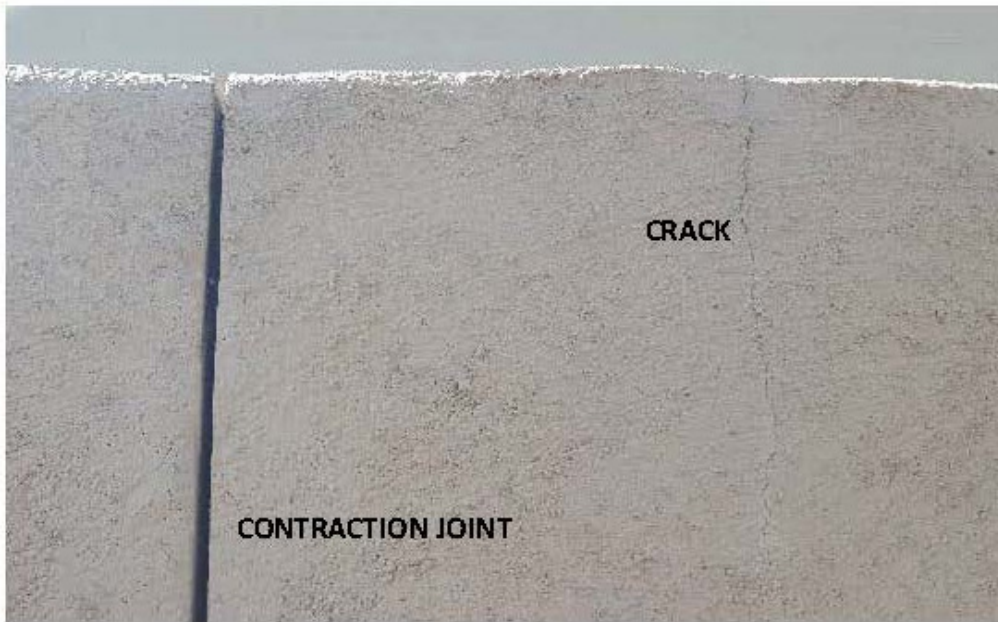


Photo 4 – Contraction Joint with Crack Forming Adjacent To It

distance to the contraction joint. An example of this is shown in the Photo 4 with the crack visible to the right of the contraction joint.

Expansion Joints

Expansion joints are used to provide locations for concrete to expand as a result of temperature increases and prevent temperature induced buckling (See Photo 5 and Photo 6). Expansion joints in a two-way soil nail wall create a point of weakness in the wall, forcing the wall to cantilever from the nail head to the joint.

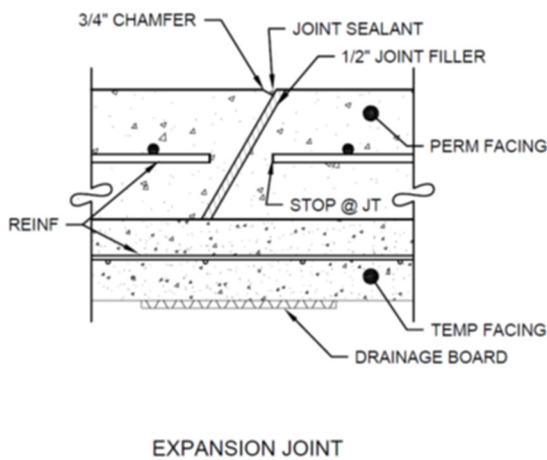


Photo 5 – Expansion Joint and Detail



Photo 6- Expansion Joint on the Left and Contraction Joint on the Right

The use of expansion joints is not recommended as experience has not shown buckling present in existing walls without expansion joints. It is believed that the nails restrain the wall from buckling. Commonly the expansion joints become locations of spalling of the concrete and frequently require maintenance.

Summary

The view of the ADSC-IAFD is that adherence to ACI standards with respect to both expansion joints and contraction joints when used in soil nail walls does not necessarily prevent cracks from appearing and thus affecting the visual appearance of the wall face. Unanticipated cracking similar to that depicted in Photo 7 has occurred on numerous soil nail projects. It is quite common for these cracks to be evident during periods of cooler weather and to 'disappear' in periods of warmer weather - in some cases on the same day.

The Owner of the soil nail wall structure must be aware that these features are a possibility and are not necessarily the result of faulty engineering or construction practices.

A few measures to aid in controlling cracks - not necessarily preventing cracks - consist of:

1. Providing some type of uniformly spaced vertical control joint on relatively long walls (walls with a large length to height aspect ratio). This may help reduce temperature induced cracking.
2. Provide steel or synthetic fibers in the shotcrete to aid in controlling shrinkage cracking.
3. Provide minimum temperature steel in shotcrete to aid in crack control for changes in volume of concrete due to temperature changes.
4. Cure shotcrete by typical ACI accepted methods to prevent shrinkage cracking due to heat of hydration.



Photo 7 – Curved Wall with Unanticipated Joints Developing

References

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- [10] Photos courtesy Subsurface Construction Company, Raleigh, NC; Moretrench, Rockaway, NJ; Boulderscape, San Jaun Capistrano, CA & Braun Intertec, Minneapolis, MN