Case 11-19

DATE: July 13, 2011

TO: MAG Specifications and Details Committee Members

FROM: Outside ROW Working Group - Niranjan Vescio, Peter Kandaris

RE: **Modification to MAG Section 340: Detectable Warnings**

Purpose: Existing section does not adequately address detectable warning material and placement requirements in accordance with ADAAG.

Revisions: Modify Section 340.2.1 to include needed detail on detectable warning color and contrast, materials, strength and performance criteria, and anchorage. Include reference to existing MAG Details 235.1 through 235.5 in Section 340.3.1.

MAG Detectable Warning Specification – Supporting Arguments

Prepared For:

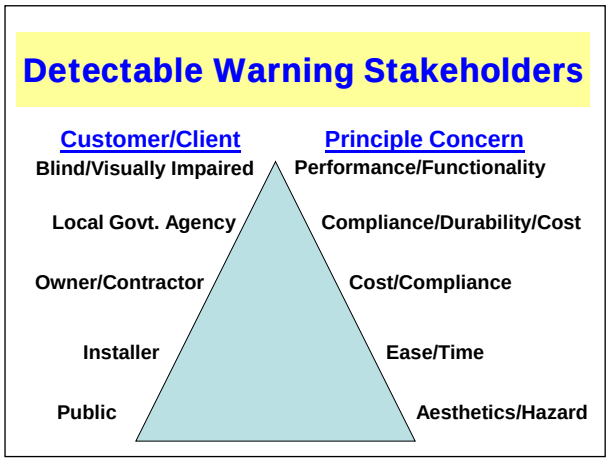
Maricopa Association of Governments, Standard Specifications and Details Committee

This document supports the edits made to the Detectable Warning specification in Arizona Uniform Standard Specifications for Public Works Construction, 1998.

Truncated dome dimensions and spacing for Detectable Warnings (DW) are defined in the ADAAG for optimal detect-ability and public safety.

Four essential DW design standards, Color & Contrast, Material, Strength & Performance, and Attachment System are left to the local authorities to define in accordance with local requirements.

The Maricopa Association of Governments (MAG) should address the interests of its various local DW stakeholders (→pyramid) by developing DW specifications for its member governments.



1. DW Color & Contrast - The ADAAG only requires that DWs be contrasted visually with adjoining surfaces, "either light on dark, or dark of light." The FHWA's visual detection study shows reds exhibited the highest luminance contrast and greatest detect-ability against light surfaces.[i] The FHWA states "*dark brick red color* (e.g. terracotta) may be a good choice where adjacent walking surfaces are light."[ii] *Terracotta is recommended for MAG public rights-of-way*; a natural southwest color that must be integral to the DW and made with UV-, heat-, and oxidant-stable pigments well-suited for the sun-belt.

2. DW Material – *Concrete is the most suitable material for DW construction* because it matches the surrounding sidewalk environment. Furthermore, concrete DWs bond best to concrete substrates, and concrete wears in a manner that sustains a consistent friction property. However, because standard concrete DWs have poor impact resistance and lack the strength and performance to achieve a compliant 20-40 year service life expected of the surrounding concrete, [iii] *higher-strength concrete should be used to manufacture DWs,* thereby preserving the look, feel, and inherent advantages of concrete. Consequently, we do not permit the use of other materials such as plastic, metal or rubber for the manufacture of DW's.

Higher-Strength Concrete (HSC): HSC can be produced to have the desired combination of physical, chemical, and mechanical properties appropriate for DWs. With HSC it is possible to form extremely durable domes true to ADAAG specification, retain an integral color throughout, have a high flexural strength, tolerate both hot and cold extremes, and meet the most discriminating strength and performance standards.

The table below compares some physical properties of HSC and standard concrete, providing perspective on the strength, durability, and performance advantages of HSC using standard concrete as the point of reference.

ASTM	Properties	Standard Concrete (Std)	Higher-Strength Concrete (HSC)
C 39-04	Compression Strength	3500 psi	12,000 psi
C 418	Abrasion	> 0.5 cm3/cm2	0.03 cm3/cm2
C 140	Water Absorption	> 4%	<0.50%
C 1262	Freeze Thaw	Fail	0.00% ➔ No change
C 1028	Slip Resistance	Fa = 0.50	Fa = 0.85
C 947-03	Flexural Yield	525 psi	2,500 psi
C 496	Tensile Strength	500 psi	2,500 psi

3. Why DW Specifications? - *Performance specifications are a necessary instrument to protect investments, address stakeholder interests, and fully define a DW system meeting local requirements.*

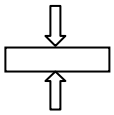
The MAG Uniform Standard Specification for Public Works Construction should:

1. Adopt a single set of functional/performance standards that apply specifically to concrete DWs.
2. Set that "performance bar" to exclude materials with a history of poor performance.

The strength and performance standards to which many concrete DWs are currently manufactured have proven inadequate for sustained strength, performance and durability. Furthermore, the ASTM C 936-08 strength/performance standards for solid concrete interlocking paving units are inadequate for DWs for the simple reason that the demands on DWs far exceed those on the concrete and pavers that form our traditional walkways. The advantages of improved strength are well noted and include optimized DW design, increased safety, lower life cycle cost, and increased service life.[iv]

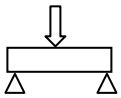
Strength and performance factors to overcome the most common causes of concrete failure including shrinkage, creep, settlement, thermal expansion/contraction, mechanical abrasion, and environmental attack appear below:

Strength Factors –



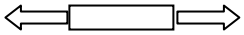
Compressive Strength > 12,000 psi per ASTM C39-04

Because high compression strength is extremely important to keep concrete truncated domes intact, a minimum 12,000 psi compressive strength concrete should be used in the manufacturing of concrete truncated domes to assure durability of this feature.



Flexural Yield Strength >2,500 psi per ASTM C947-03

Because detectable warnings can be subject to the extreme loads of vehicle drive-overs (which can create opposing axial forces), require a minimum of 2,500 psi flexural strength. Concrete pavers of 1,100 psi flexural strength do not survive such flexural stress.

Tensile Strength >2,500 psi per ASTM C496 

Because standard concrete can be strong in compressive strength, but comparatively weak in tensile strength, and lack the ductility to survive extreme environmental cycles, the latter being most critical for maintaining structural integrity during both hot/cold and wet/dry extremes of Arizona, require no less than 2,500 psi tensile strength.

Standard concrete is generally less that 15% as strong in flexural as compression.[v,vi,vii] Higher strength concrete mixtures can achieve flexural and tensile strengths at least 20% of the compressive and such standards must be required of DWs in order to achieve the desired service life.

Performance Factors –

Freeze/Thaw => 0.00% material loss per ASTM C 1262

Because ice expansion during freeze/thaw cycles creates internal pressure that can break apart weak concrete, require zero material loss after a 50 cycle test in order to realize an extended service life for DWs.

Water Absorption <0.50% per ASTM C 140

Because moisture penetration can lead to thermal expansion tension in the summer heat, require no more than 0.50% water absorption into the DW material.

Slip Resistance >Fa=0.85 per ASTM C 1028

Because slip resistance of advanced concretes can vary with product formulation and finish, establish greater than 0.85 slip resistance per ASTM C 1028 as the minimum standard of performance to ensure this very important performance factor is not compromised in design for gains in other factors.

Abrasion <0.03 cm^3/cm^2 per ASTM 418

Because abrasion is greatly increased by the introduction of foreign particles (e.g. sand) abundant in the desert, and abrasion loss can leave the surface more susceptible to water permeation, require no more that 0.03 cm^3/cm^2 material loss per ASTM 418.

4. Why DW Attachment? – A monolithic attachment of the DW to the substrate is key to a strong performance of the DW over the long term. Wet-set installation using a proven wet-set anchoring mechanism that assures constant contact of the DW's bottom surface with the concrete slurry as it chemically cures and outgases is strongly recommended because this is the only assurance of a complete and lasting void-free attachment to the substrate.

---

[i] DW Visual Detection Study: http://www.access-board.gov/research/dw-fhwa/report.htm; p52, p20.
[ii] DW Visual Detection Study: http://www.access-board.gov/research/dw-fhwa/report.htm; PDF Page 66
[iii] Concrete Network; http://www.concretenetwork.com/concrete/walkways/construction.html
[iv] Slag Cement Assoc.: http://www.slagcement.org/image/123800_c_sU128801_s_i185541/No14_Compress_Strength.pdf
[v] National Ready Mix Concrete Association; http://www.nrmca.org/aboutconcrete/cips/16p.pdf
[vi] STD Concrete Compressive to Tensile; http://www.highbeam.com/doc/1G1-111616523.html
[vii] Cement Technology; http://www.cement.org/tech/faq_flexural.asp

Revisions to MAG Section 340:

Concrete Curb, Gutter, Sidewalk, Sidewalk Ramps, Driveway and Alley Entrance

340.2.1 Detectable Warnings

Truncated dome dimensions and spacing for Detectable Warnings are defined by the Americans with Disabilities Act Accessibilities Guidelines (ADAAG) for optimal detect-ability and public safety. Four essential detectable warning design factors, Color & Contrast, Material, Strength & Performance, and Attachment System, are defined in the following subsections to suit local performance requirements.

Detectable warnings shall consist of raised truncated domes aligned in a square grid pattern in conformity to the ADAAG~~Americans with Disabilities Accessibility Guidelines~~. Truncated domes shall have the following nominal dimensions: base diameter of nominal 1.0 inches (0.9 inches minimum) top diameter of 50 percent of the base diameter minimum to 65 percent of the base diameter maximum, and height of nominal 0.2 inches. Dome center-to-center spacing of 2.35 inches, measured between the most adjacent domes on the square grid. Dome center-to-center spacing for radial installations shall be 1.6 inches minimum and 2.4 inches maximum with a base-to-base spacing of 0.65 inches minimum. Detectable warning edges shall be sized and installed so that dome spacing is maintained across adjoining edges.

340.2.1.1 Color & Contrast Detectable warnings shall contrast visually with adjoining surfaces, either light-on-dark, or dark-on-light. Use white where adjacent walking surfaces are dark (e.g. asphalt), and a dark brick red color where adjacent walking surfaces are light (e.g. standard gray concrete). Other colors shall be approved by the jurisdictional agency prior to installation.~~Visual contrast shall be obtained by color, use safety yellow or other approved color.~~ The color shall be ~~an~~ integral to the detectable warning~~part of the material surface~~. ~~The material is to be durable with a non-slip surface not subject to spalling, chipping, delamination, or separation.~~

340.2.1.2 Material Detectable warnings shall be constructed of high-strength concrete material only. The material is to be durable with a non-slip surface not subject to spalling, ~~-~~chipping, delamination.~~, or separation.~~ Detectable warning tiles shall have a design service life of 30 years and carry a warranty against manufacturer defect of at least 10 years.

340.2.1.3 Strength & Performance High-strength concrete detectable warnings shall meet the following minimum ASTM standards for strength and performance:

Strength/Performance Test	Minimum Requirement	ASTM Method
Compressive strength	>12,000 psi	ASTM C 39-04
Tensile strength	>2,500 psi	ASTM C 496
Flexural yield strength	>2,500 psi	ASTM C 947-03
Slip Resistance	>FA=0.85	ASTM C 947-03
Abrasion Resistance	<0.03 cm^3/cm^2	ASTM 418
Water Absorption	<0.50%	ASTM C 140
Freeze/Thaw	0.00%	ASTM C 1262

Manufacturer conformance with the above minimum requirements shall be demonstrated by furnishing the jurisdictional agency with results of independent laboratory tests. The jurisdictional agency may request detectable warning samples for additional supplier-paid quality assurance testing at an agency-selected laboratory. All detectable warnings shall be approved by the local jurisdictional agency prior to installation.

DRAFT

340.2.1.4 Anchoring System High-strength concrete detectable warning may be either cast-in-place or recessed. Cast-in-place detectable warnings shall be installed directly into freshly poured concrete (i.e. wet-set) with a proven wet-set anchoring mechanism that assures constant contact of the detectable warning bottom surface with the concrete slurry as it cures, thus rendering the ramp a single monolithic structure. The thicker and heavier detectable warnings lowered into preformed recesses in the concrete substrate must demonstrate a firm fitting into metal reinforced frames without gaps along the edges that can channel water, sand, or debris. They must also be able to resist movement (i.e. sliding, rocking, or lifting) once in service.

340.3.1 Detectable Warnings The detectable warning surface shall be located so that the edge nearest the curb line is 6 inches minimum and 8 inches maximum back from the face of curb. Detectable warning surfaces for railroads shall be located so that the edge nearest the rail crossing is 6 inches minimum and 8 inches maximum from the vehicle dynamic envelope.

Detectable warnings shall be installed perpendicular to the direction of pedestrian/wheelchair travel and have a minimum width of 24 inches measured perpendicular to the edge of the roadway or rail crossing. The base surface of detectable warnings shall be installed flush with the adjacent walkway surface; the truncated domes shall extend above the walkway surface. The boundary between detectable warnings and the adjacent walkway shall provide a flush uniform surface that will not cause ponding of water nor present a tripping hazard. Partial domes at the edge of the detectable warning shall be made flush to match the base surface of the detectable warning. Detectable warnings installed on curb ramps shall extend the full width of the ramp depression.

Detectable warnings installed on sidewalk ramps shall modify the sidewalk concrete thickness at the detectable warning to provide a minimum thickness of four-inches (4”). When detectable warnings are modules inset into the sidewalk ramp, the bottom surface of the sidewalk shall be lowered a distance equal to or greater than the module thickness to maintain the minimum sidewalk thickness. The sidewalk bottom surface shall have a minimum transition taper length of 12” between the thickened and normal/depth sections of sidewalk.

Detectable warnings shall be installed as shown in Details 235.1 through 235.5.

DRAFT