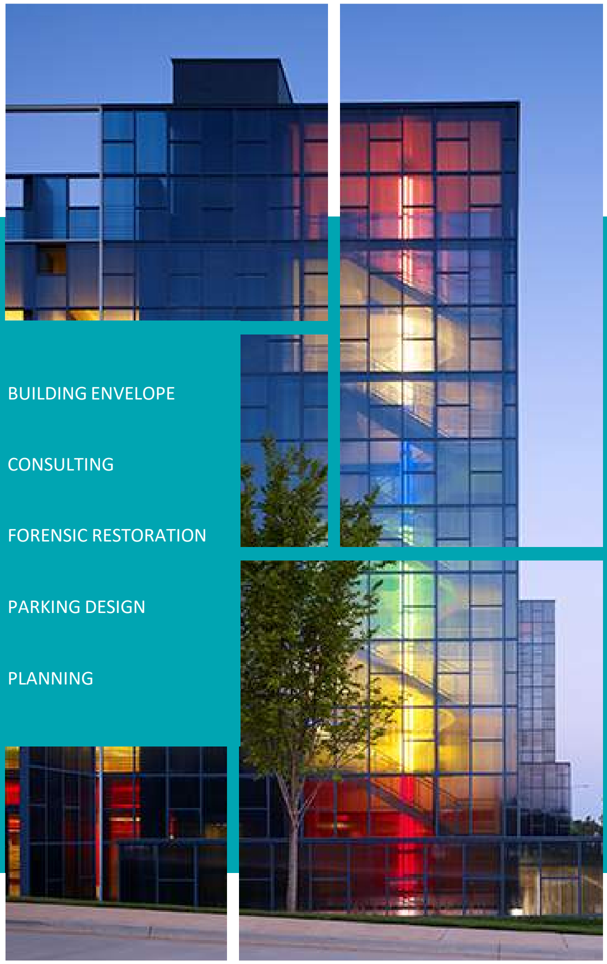
WALKER CONSULTANTS



BUILDING ENVELOPE

CONSULTING

FORENSIC RESTORATION

PARKING DESIGN

PLANNING

DESIGN AND MAINTENANCE CONSIDERATIONS FOR PARKING STRUCTURES

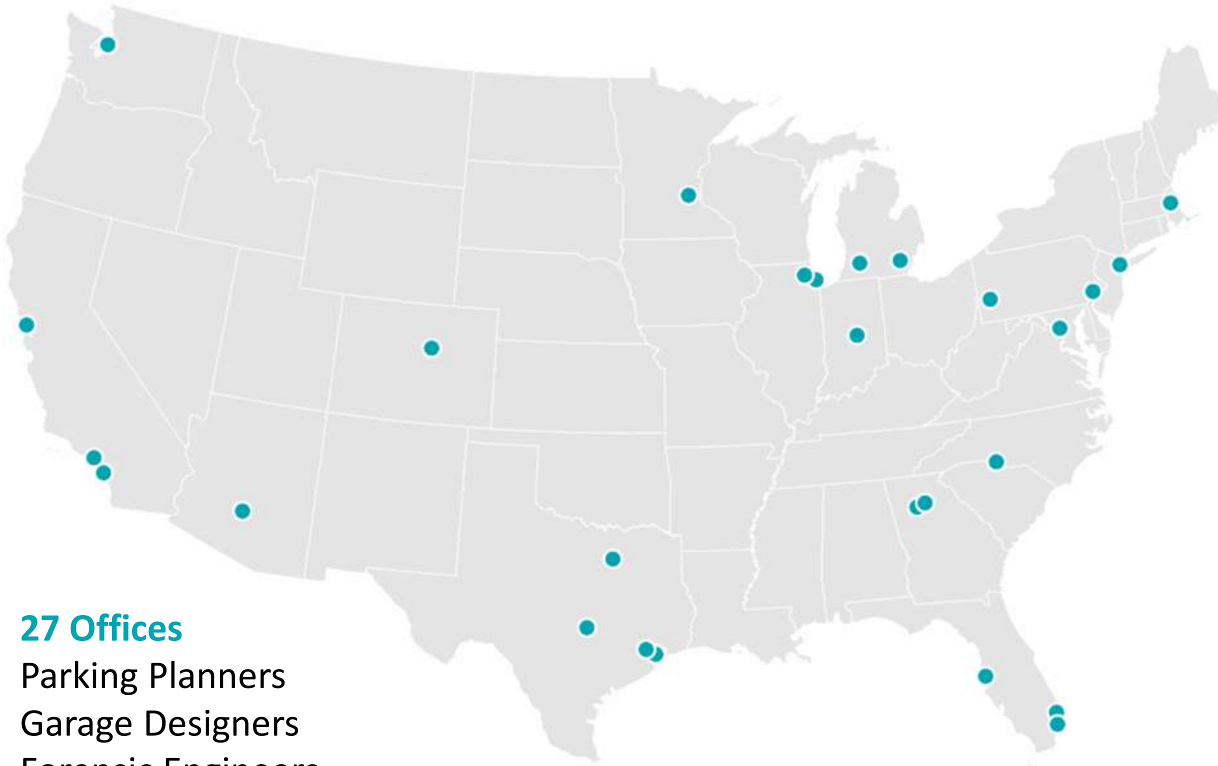
Minnesota Concrete Council
October 12, 2023

WALKER CONSULTANTS

Carl Schneeman, PE

Managing Principal

Minneapolis Office



27 Offices
Parking Planners
Garage Designers
Forensic Engineers

TALKING POINTS

Parking Needs

Planning & Layout

Functional Design

Durability Considerations

HOW MANY PARKING SPACES DO WE NEED? DEFINE.

- Minimum Parking Requirements: How many spaces to satisfy the jurisdiction's code?
- Operational Adequacy: How many spaces do I need to accommodate typically busy demand?
  - On site
  - Off site
  - Valet
  - Through other modes & transportation demand management (TDM)
- Lending, Tenant and Other Leasing Requirements
- Cost: How many spaces can my project afford to build, operate and maintain?

PLANNING FOR STRUCTURED PARKING

Parking Supply – number of parking spaces available to serve a development

Parking Demand – number of parking spaces required to satisfy visitor, employee, and resident parking needs on a given day

Effective Parking Supply – cushion of extra spaces to account for infrequent increases in demand, misparked vehicles, minor construction, debris, etc.

Recommended Parking Supply = Parking Demand + Effective Parking Supply

Parking Ratio – number of parking spaces that should be provided per unit of land use

Shared Parking – use of a parking space to serve two or more individual uses without conflict or encroachment

SO, HOW MUCH PARKING IS REQUIRED?

Review municipal zoning ordinance – “Off-Street Parking”

- Ostensibly require owners to provide sufficient off-street parking spaces to prevent spillover
- Typically required parking by individual land use only and just add them up
- Rarely based on research on customized for local conditions
- Typically assumes free parking
- Typically found to be materially above actual demand, with some exceptions.

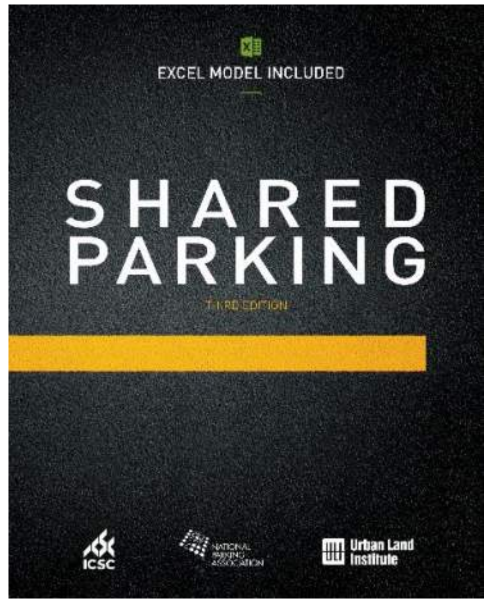
TWIN CITIES ELIMINATING PARKING REQUIREMENTS

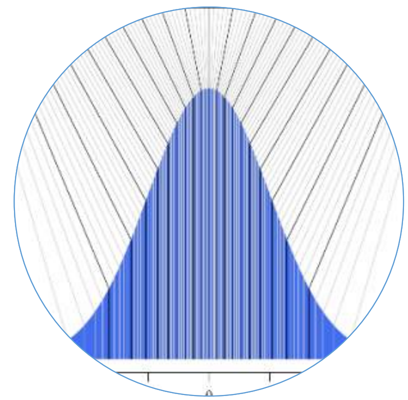
Both Minneapolis and St. Paul have approved changes to remove minimum requirements in their zoning codes in 2021

- Eliminates minimum parking requirements
- Introduces needs to invest in TDMP to discourage single-occupant vehicles (SOV)
- Both cities have maximums introduced
- Can be challenged based on local conditions
- **But without requirements, how to determine how much parking we need?**

HOW *SHOULD* WE DEFINE HOW MANY SPACES WE NEED?

- ULI Standard
- Represents base parking ratios at the 85th percentile
- Recommendation based on busiest hour, day, and month
- Method used for 40+ years in the U.S. (since 1983)
- Commonly-used practice throughout the U.S.
- Accounts for multimodal opportunities

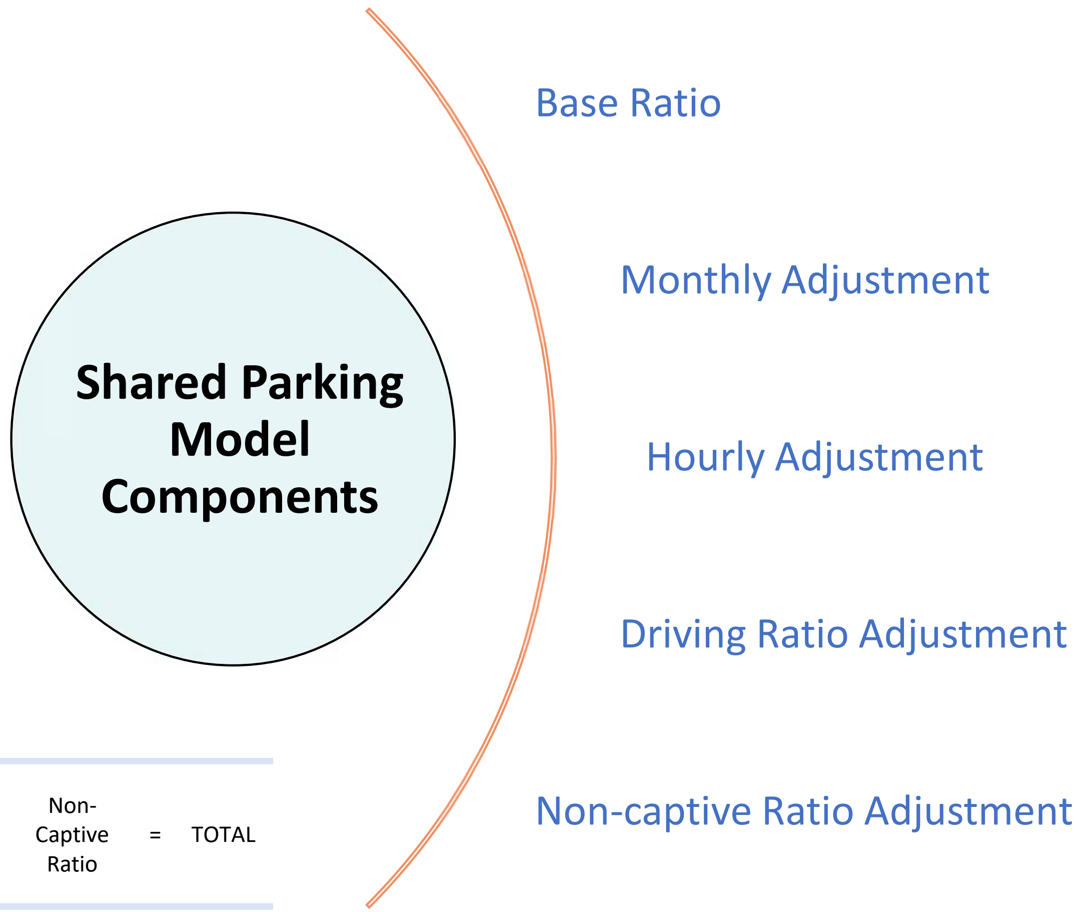




85th Percentile

SHARED PARKING METHODOLOGY

- 19 hours per day
- 2 days per week (weekday and weekend)
- 12 months per year
- 456 different calculations
- 45 different land uses



Land Use Units (Number of rooms, square footage, etc.)	X	Standard or Base Parking Generation Ratio	X	Monthly Factor	X	Hourly Factor	X	Driving Ratio	X	Non-Captive Ratio	=	TOTAL

GOAL OF SHARED PARKING: RIGHT SIZE PARKING AND NOT OVER OR UNDER BUILD

- Provide Adequate on-site parking to avoid use of off-site and spillover
- Reduce costs
- Avoid Congestion with under parked streets
- Limit heat-island effects
- Promote highest and best use of real estate
- Significant walkability and other environmental benefits

Example of empty, rarely used spaces

EXAMPLE PROJECT

Mixed Use Facility

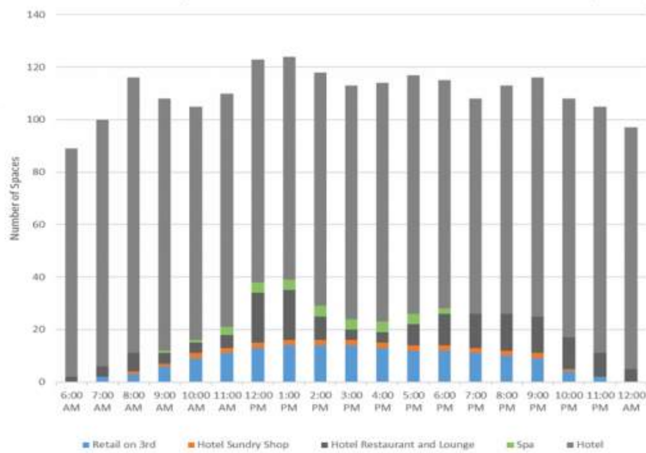
- *Hotel*
- *3 Café/Bars*
- *Street Facing Retail*
- *Sundry Shop*
- *Spa*

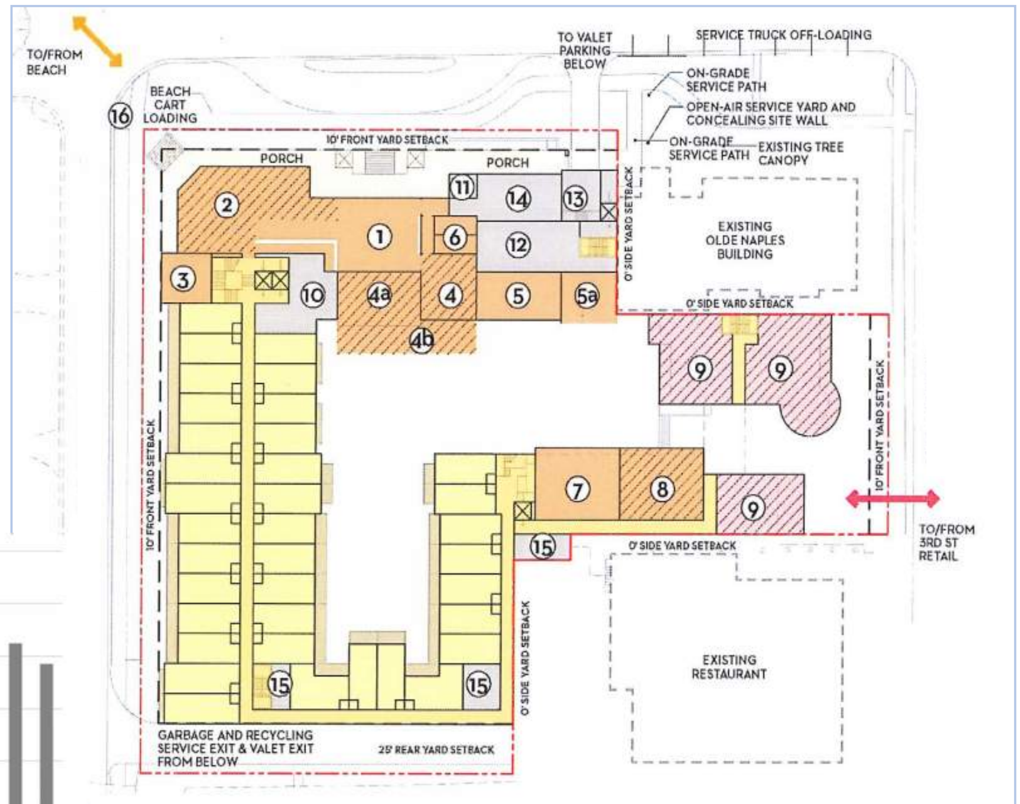
PARKING NEEDED

City Zoning Requires 151 spaces

Shared Parking recommends 129 spaces

15% reduction





SHARED PARKING MODEL RESULTS

- Typically, reductions range from 10% to 30% but …
  …it depends heavily on the land uses.
  Will your multifamily project really share parking?

- Reductions of 40% or more are highly unusual.

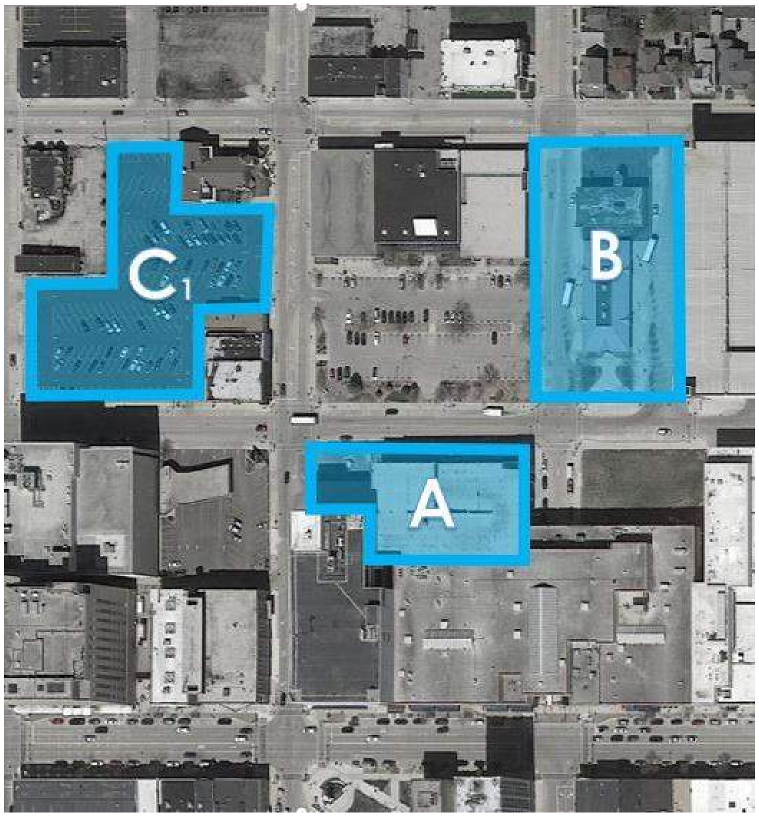
- Reductions are not usually rideshare, TDM, etc. **Rather, It's that requirements are too large to begin with.**

- BUT Reductions may result in:
  - The need to build fewer spaces and therefore a reduction in costs.
  - The ability to build a full development program that may have been site or cost prohibitive.
  - The ability to build a larger program.

I KNOW WHAT I NEED – NOW WHAT?

- Identify site geometry and property dimensions
- Account for setbacks and adjacent buildings
- Review traffic patterns and user destination
- Where are pedestrian destinations?
- Multiple destinations?
- Location of stair/elevator cores.
- Size of site – can parking layout be efficient?

  (Reasonable designs are around 320 sf/car)



PARKING FACILITY TYPES

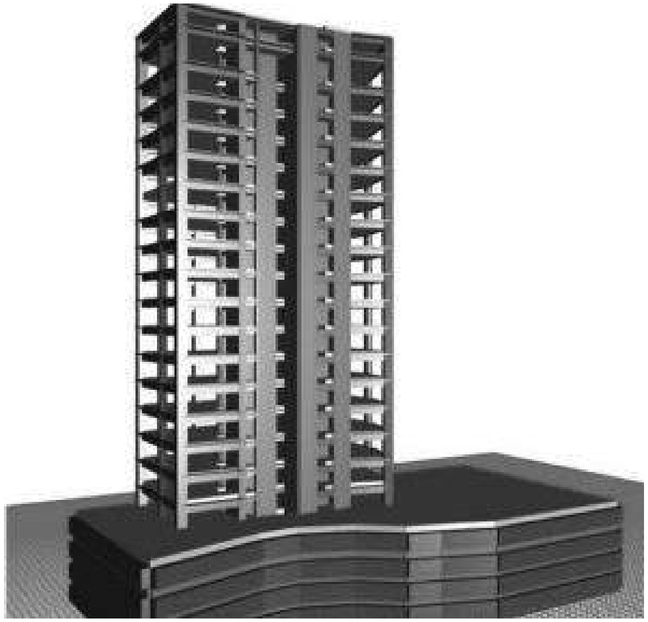
- Parking lot (surface lot)
- Parking structures
  - Ramps, Garages, Parkades, etc.

Parking Structures can be quite varied
  - Open parking structure
  - Enclosed parking structure
  - Above grade
  - Below grade

Surface $ < Open $$ < Enclosed $$$ < Below Grade $$$$

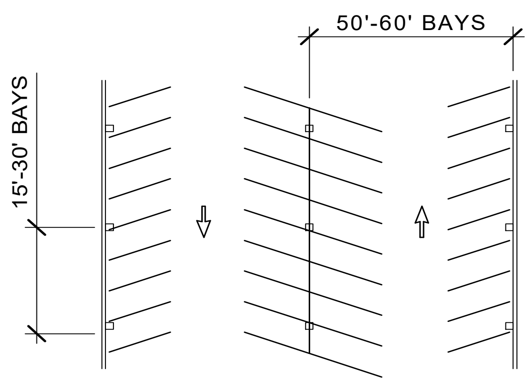
PARKING FACILITY TYPES

- Podium parking facilities
- Wrapped parking
- Stand Alone

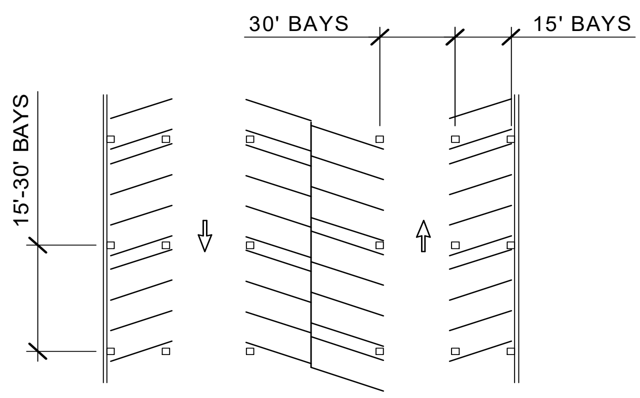


BUILDING BLOCKS

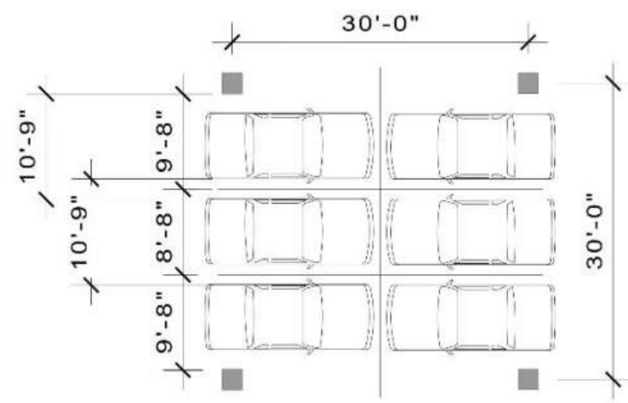
- **Long (or clear) span:** a structural system that spans the full width of the parking bay/module
- **Short span:** A structural system that spans less than the full module, resulting in columns between parked vehicles. Typical below buildings or plazas, 30’ x 30’ grid most common
  - **Watchpoint: 27’-0” bays are too tight – have to account for columns, AND doors!**



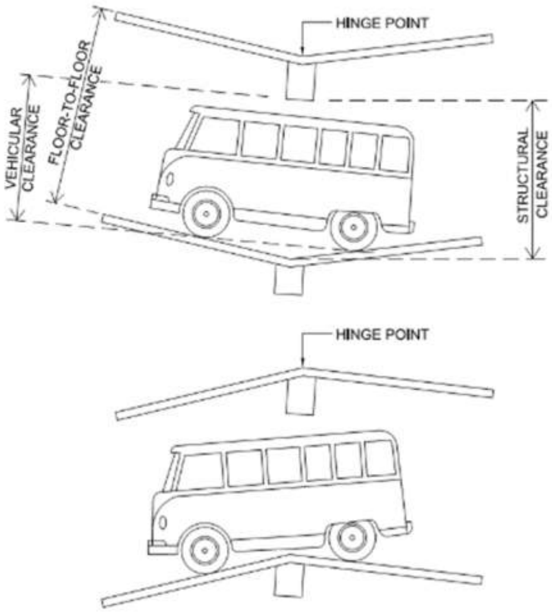
LONG SPAN CONSTRUCTION



SHORT SPAN CONSTRUCTION



BUILDING BLOCKS



- Maximum parking ramp slope = 6.67% (recc. 6% max.)
- Maximum non-parking ramp slope = 16%
  - Folks prefer 8-12% typically
- Maximum change in slope without transition = 8%
  - Bottom outs: Greater than this requires transition slopes
- IBC Min. Clearance = 7’-0”
  - Actually was 7’ MAX historically
- ADA van clearance = 8’-2”
  - Floor to floor = 8’-2” + 3’-0” structure +2” tolerance = 11’-4” recommended
- Typical mixed use = 12’ to 14’ clear

BUILDING BLOCKS

Turning Bay Recommendations

- No End bay parking:

  T = 30’-0” clear

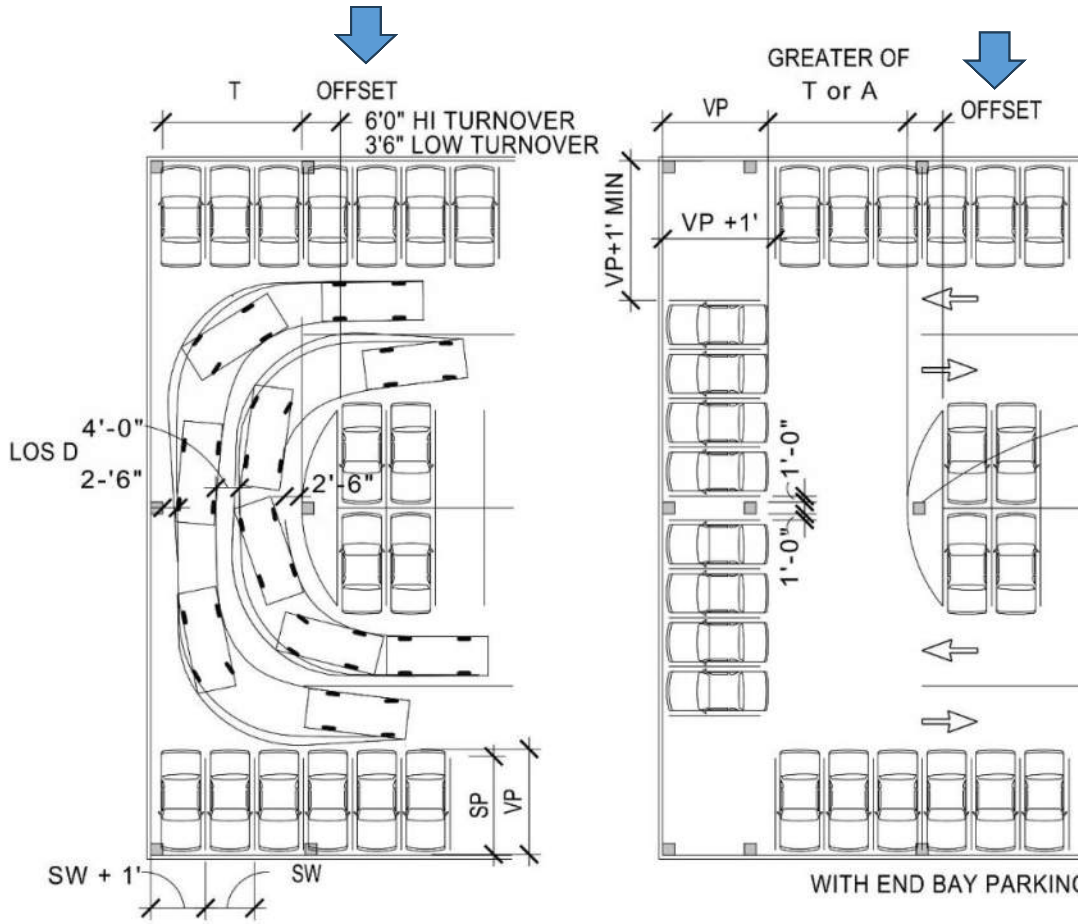
  (two-way traffic)

- With End bay parking:

  VP + T = 48’ clear

  (two-way traffic and 18’-0” stall)

Watchpoint: Offsets “ “ are also needed to aid turns!



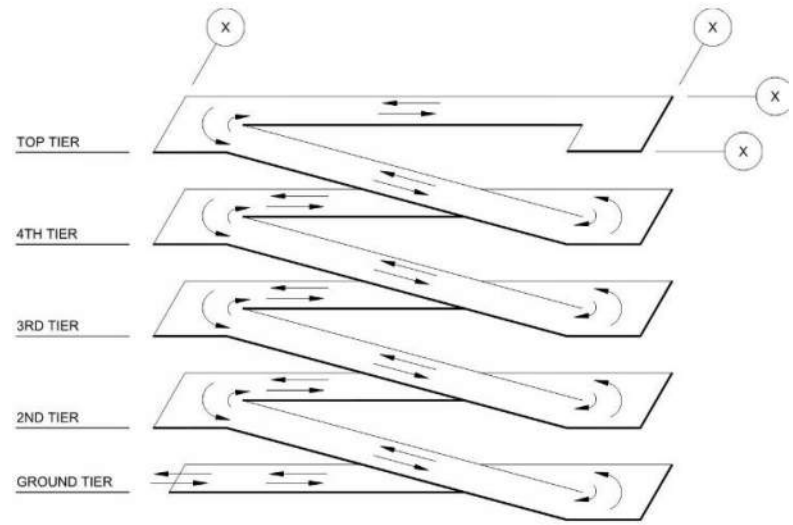
2-WAY TURNING BAY

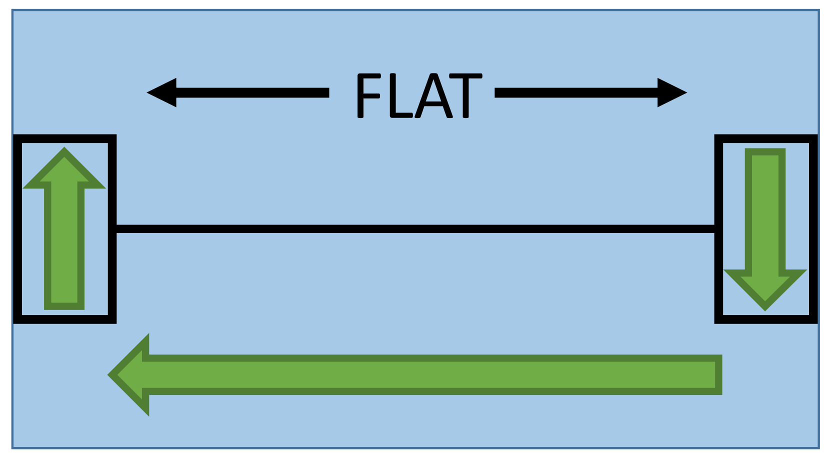
SITE SELECTION

Site selection basics

- Minimum site dimensions – single ramp
  - 200’ x 120’
    - (don’t forget to add façade thickness!)

  - No end-bay parking
  - Requires end ramps (“jump” ramps)
  - **Single bay of flat parking**



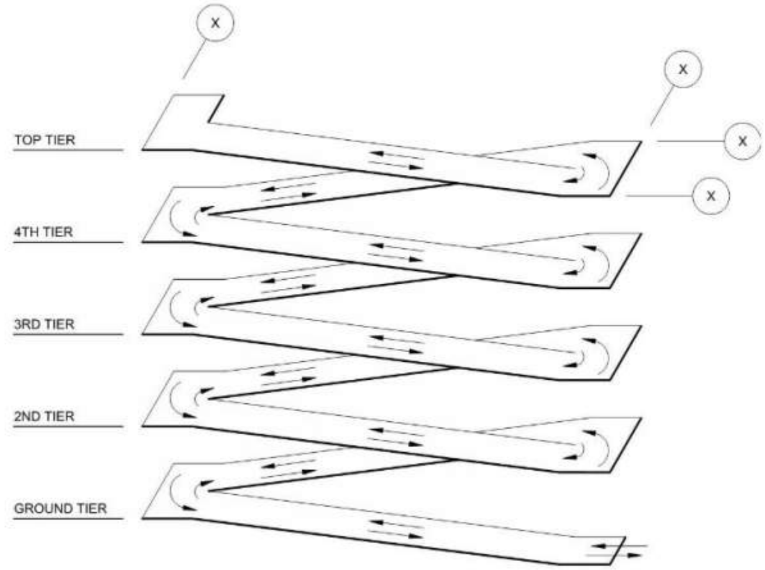


SITE SELECTION

Site Selection Basics

- Minimum site dimensions – 2 ramps
  - 140’ x 120’
  - No End-Bay Parking
  - No Flat Parking
  - …but a challenge for ADA

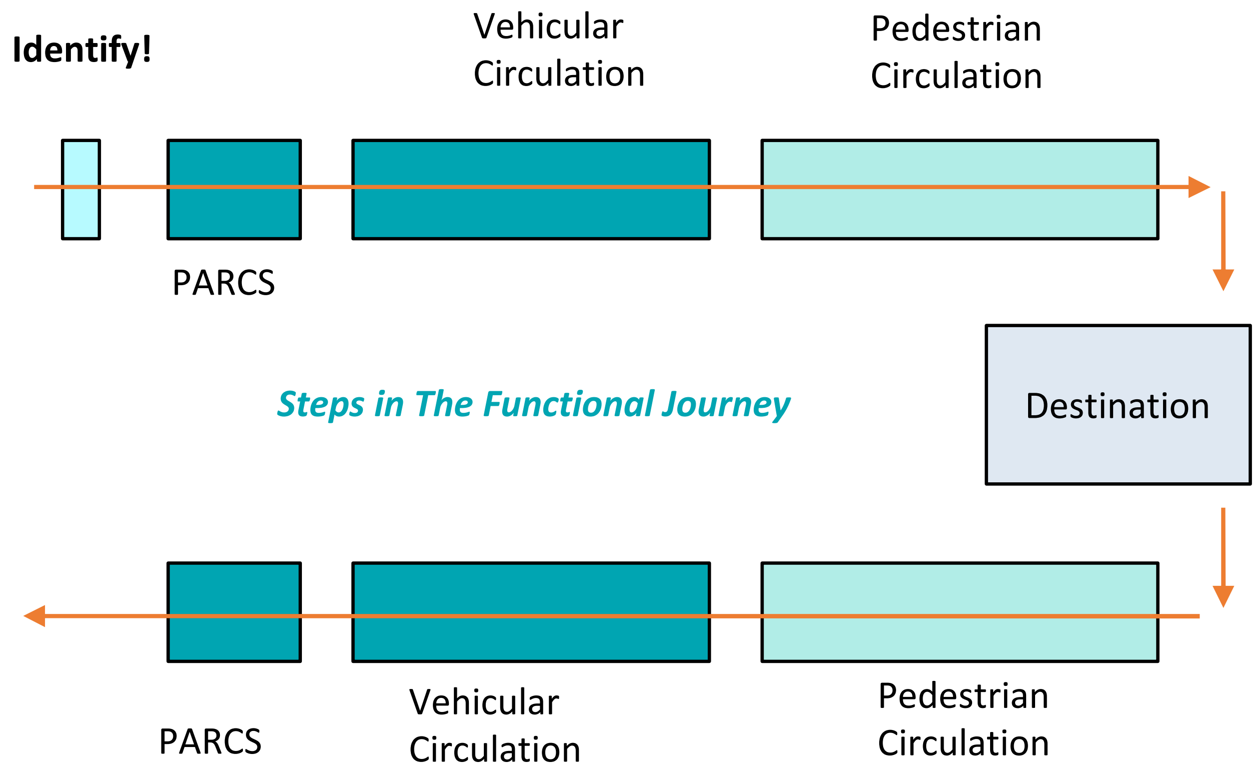
There’s a lot of options, so let’s talk about **Functional Design**



WHAT IS FUNCTIONAL DESIGN?

Everything to do with the use of the building for parking…

…with consideration of pedestrian and vehicular flow.



WHAT AFFECTS FUNCTIONAL DESIGN

Types of users

- Frequent users
  - Office parking, residential
- Infrequent users
  - Retail, hospital
- Long term parking
  - Airport, monthly, student
- Short term parking
  - Shopping centers

WHAT AFFECTS FUNCTIONAL DESIGN

- Pedestrian needs
- Dimensions of the site
- Parking Geometrics
- Peak hour volumes
- Flow capacity

All have a **Level of Service** influenced by the project Budget

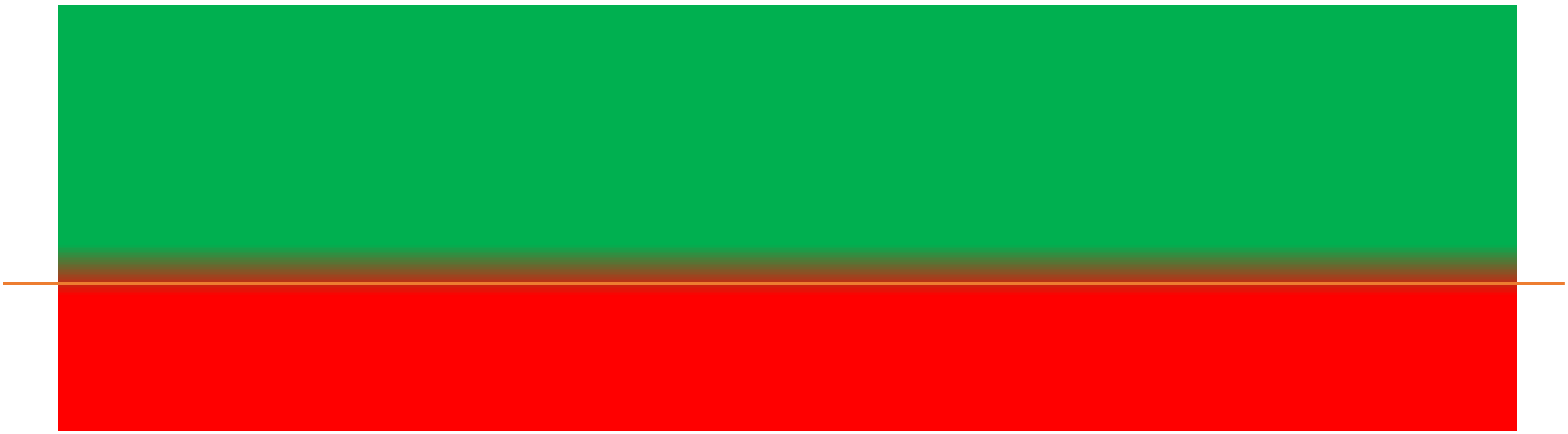
LEVEL OF SERVICE

- What is Level of Service (LOS)?
    - *A qualitative measure used to relate the quality of service*
- Modeled after traffic engineering standards
- Communication tool used to describe the quality of a Functional Design
- Expresses the balance of:
    - User needs/wants
    - Business, cost and operational requirements
- **Promotes consistency in design**

LEVEL OF SERVICE

PARKING Use

Traffic Engineering Definition



LEVEL OF SERVICE

<u>LOS Criteria</u>

- Parking stalls
- Geometrics / Turning
- Flow capacity
- Lighting Levels
- Walking distances
- Clear height
- Slopes
- Number of turns to top
- % Spaces on Flat Floors

GUIDELINES FOR LOS SELECTION

A *B* *C* *D*

High turnover parking shopping centers, VIP's airport 0-3 hrs.

Hospitals, airport 3-24 hrs.

Office or University Visitors, stadium/arena, airport 24+ hrs.

Monthly parking, employee parking

Student parking

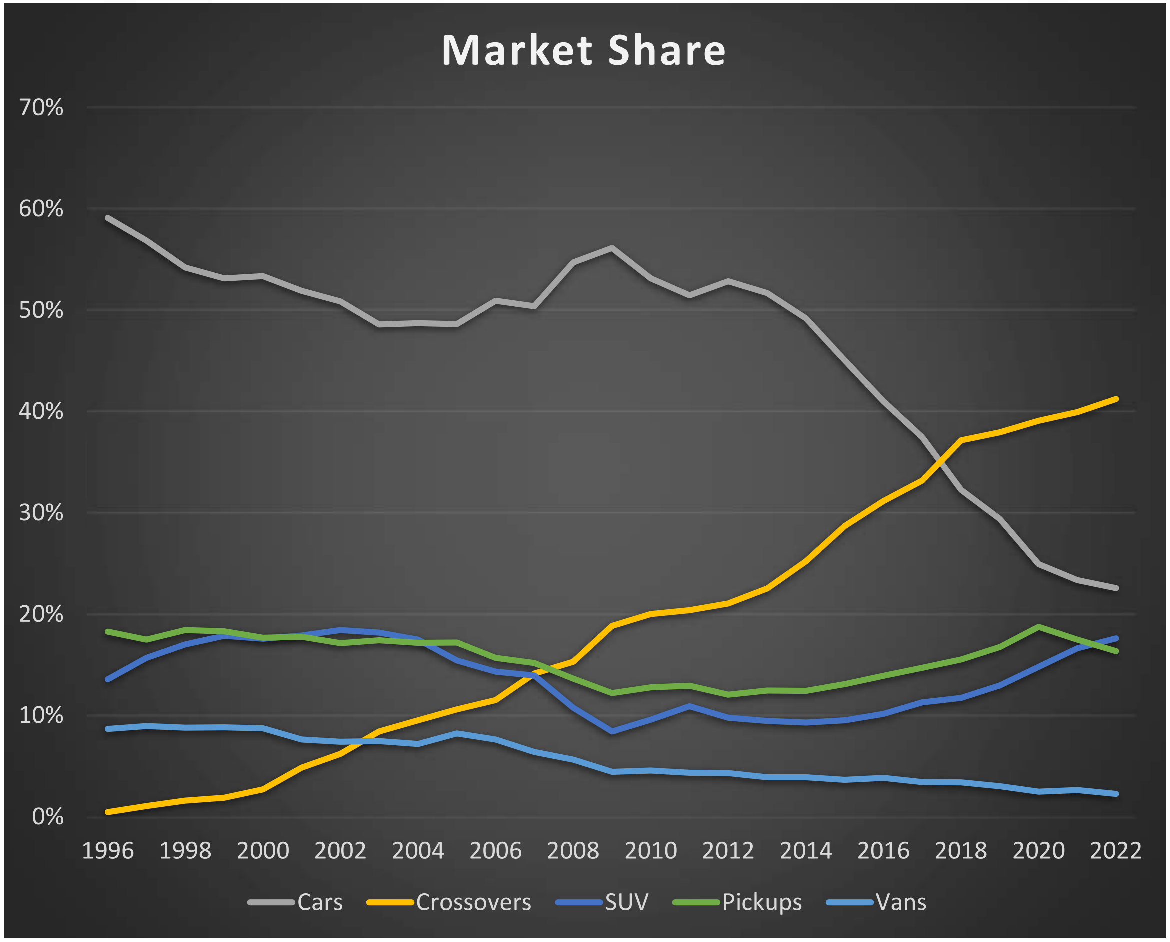
VEHICLE SIZES

- Parking consultants use a design vehicle to establish parking geometrics
- We design for the 85^{th} percentile vehicle
- Track yearly vehicle sales to establish the design vehicle

(It's been consistent since the late 1990s)

RECENT TRENDS: CROSSOVERS DOMINATE THE CONVERSATION

- Crossovers have steadily gained market share since first introduced in 1994
- Since 2010 or so sedans have been replaced by crossovers
- Crossovers, Pickups & SUVs are **75%** of all sales!
- Pickups represent about 16% in 2022



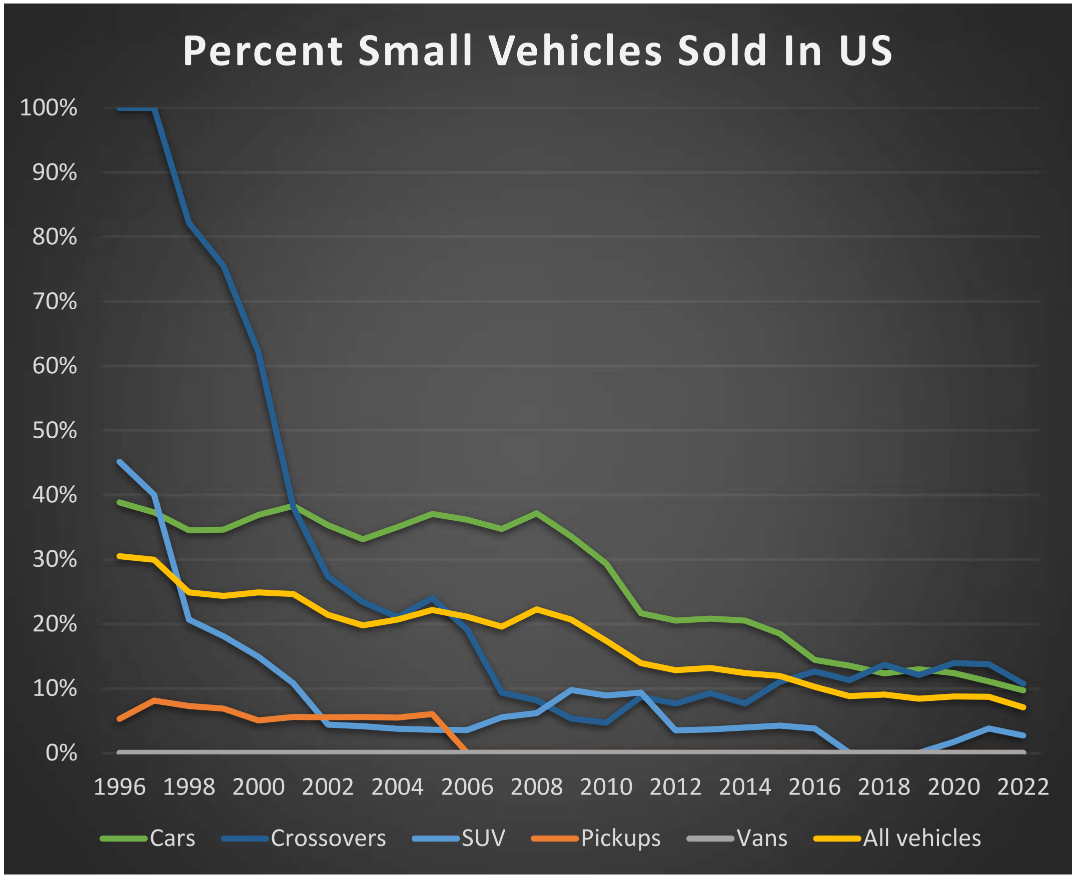
Walker Consultants analysis of Automotive News Data, Annual US Sales, 1996-2022

DESIGN VEHICLE

- National Parking Association Design Vehicle:

DV = 6’-7” wide x 16’-10” long

- Through 2022 “Compact” cars are ONLY about 7% of Vehicle sales!

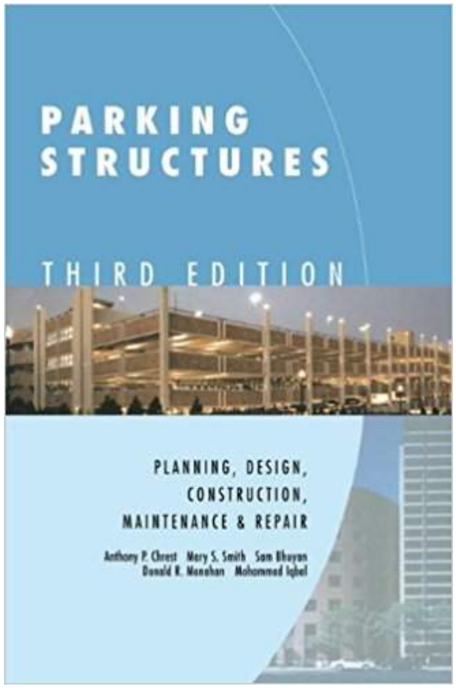


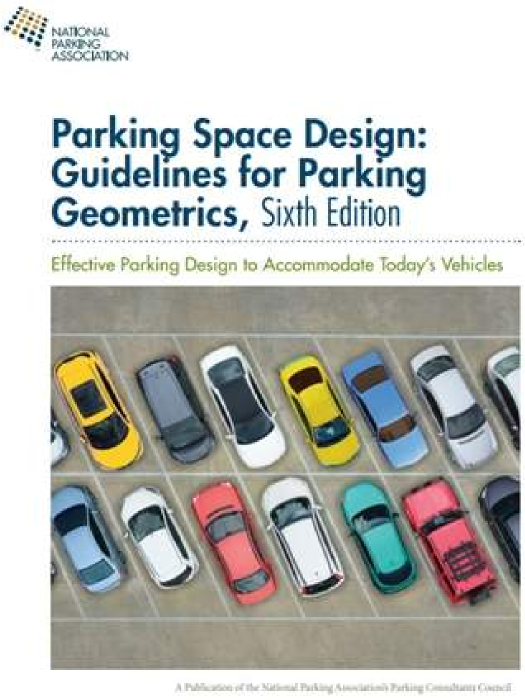
Walker Consultants analysis of Automotive News Data, Annual US Sales, 1996-2022

GEOMETRICS

<u>Most encountered geometrics</u>

1. Stall width
2. Module
3. Circulation system
4. Angle of park
5. Slopes
6. Turns
7. Walking distances





GEOMETRICS

Stall Width

The nominal dimension of the width of the stall, measured at right angles to the stall edges. We design stalls to be 20” to 30” wider than the design vehicle depending on the desired LOS.

	LOS	Width	
	D	8’-3”	
Office →	C	8’-6”	
	B	8’-9”	
	A	9’-0”	← Retail

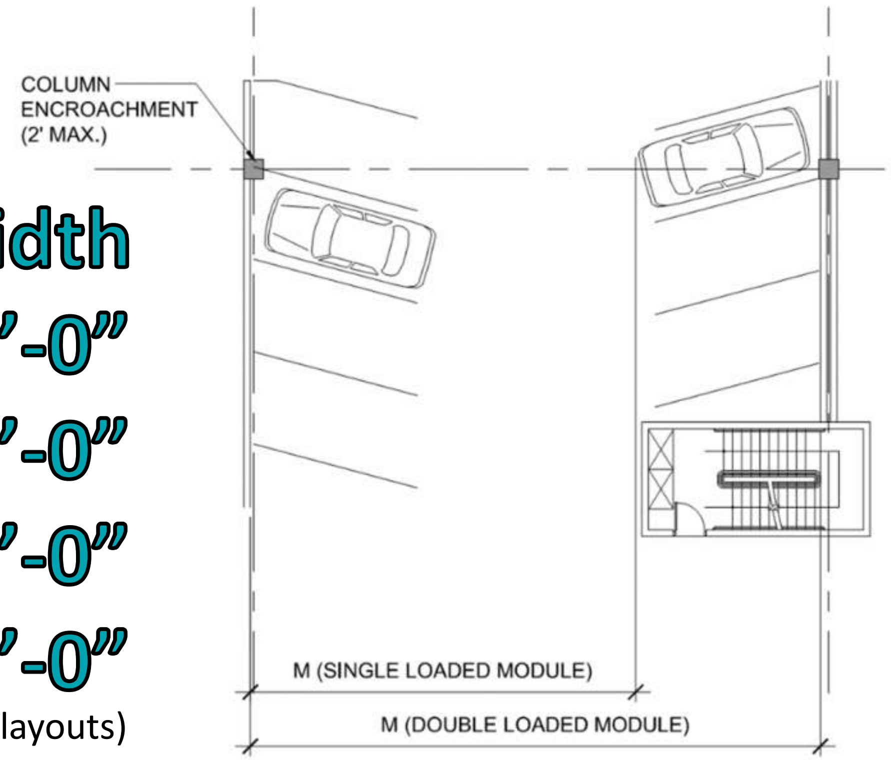
GEOMETRICS

Module

- The **out-to-out dimension** of rows of parking stalls and the aisle providing access to the stalls
- Module = Vehicle Projection + Aisle + Vehicle Projection

LOS	Width
D	58'-0"
C	59'-0"
B	60'-0"
A	61'-0"

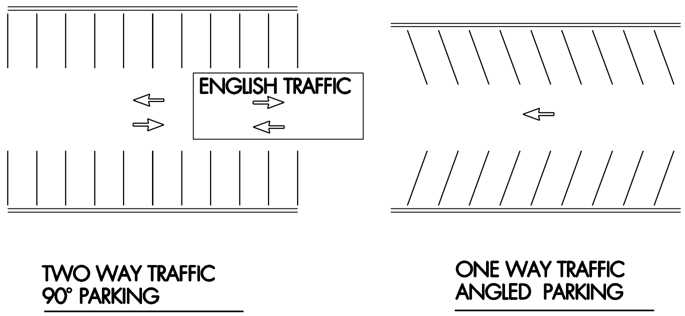
(For 90-degree layouts)



THE MOST NATURAL ANGLE OF PARKING IS 60 DEGREES - WHY NOT ALWAYS USE THAT ANGLE?

- It is generally acknowledged that the most natural angle of parking is about 60 degrees
  - If line stripes are absent or badly worn, cars will naturally park at that angle
  - At other angles, many cars will naturally park closer to 60 degrees than the stall is striped
  - This is clearly confirmed by the fact that flow capacity of a parking aisle is maximized at 60 degrees
- For these reasons, in the 60s/70s/80s Parking Designers regularly used 60 degrees for most angled parking. However, due to the efficiency penalty it’s less likely to used today
- If angled parking is desired, consider using 75-degree parking if it fits on the site, because the efficiency will be competitive with that for 90-degree parking while having the desired benefits of one-way traffic flow

CIRCULATION



Two-Way Traffic Advantages

- Better pedestrian visibility
- No wrong way
- Most efficient search
- Typically more efficient*
- Reduced travel distance both in and out

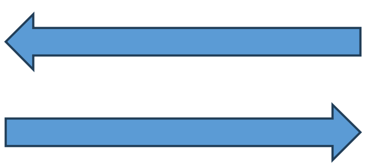
One-Way Traffic Advantages

- Easier parking maneuvers
  - 60 degree most natural
- Better flow capacity
- Separation of inbound and outbound traffic
- Less traffic conflict – Easier Back out
- More flexible for future changes in auto size

CIRCULATION - WHEN TO USE

<u>Two-Way Traffic Use</u>

- Small to moderate size decks
  - Regular users
  - Low turnover
- Efficient parking
- Maximize Parking Count



<u>One-Way Traffic Use</u>

- Larger decks
- Tall decks
- High turnover
- Better Flow capacity
- Site width limitations

CIRCULATION – UP AND DOWN, IN AND OUT!

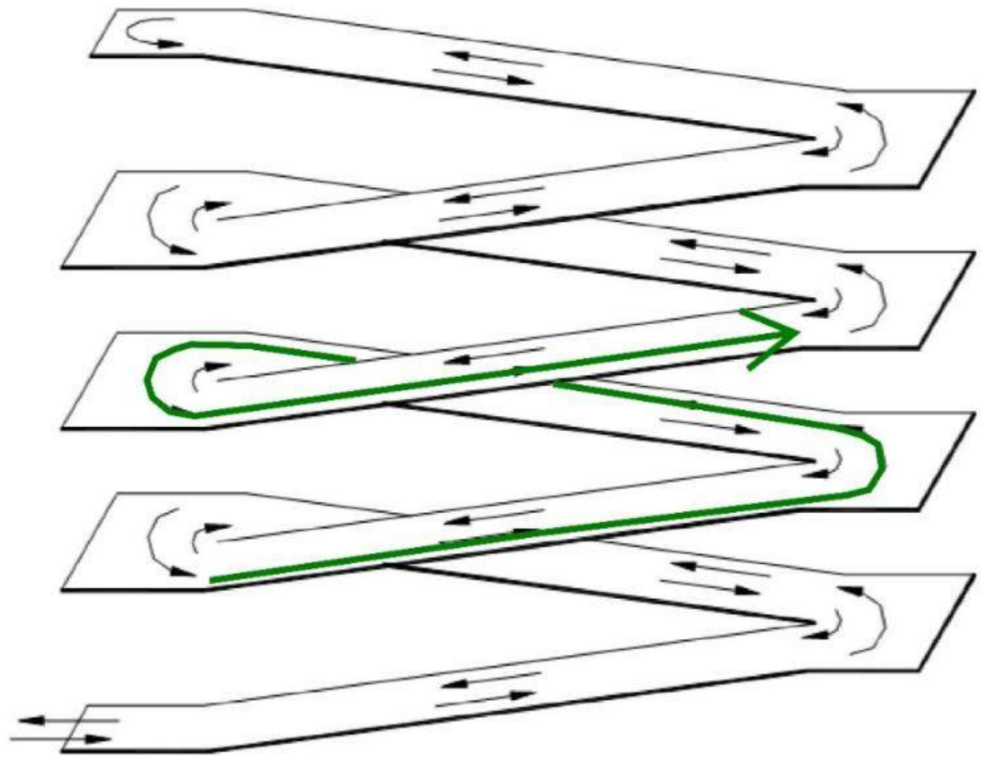
Helix

- Provide access between floors in a parking structure
- In a parking structure, a series of sloped parking bays and/or express ramps to provide floor-to-floor circulation
- **Single-Threaded Helix:** A helix which rises **one** floor with each 360 degrees of revolution
- **Double-Threaded Helix:** A helix which rises **two** floors with each 360 drees of revolution. Two treads are accommodated within the footprint

CIRCULATION

<u>Single-Threaded Helix</u>

- Goes up **one** story for each 360 degrees of revolution



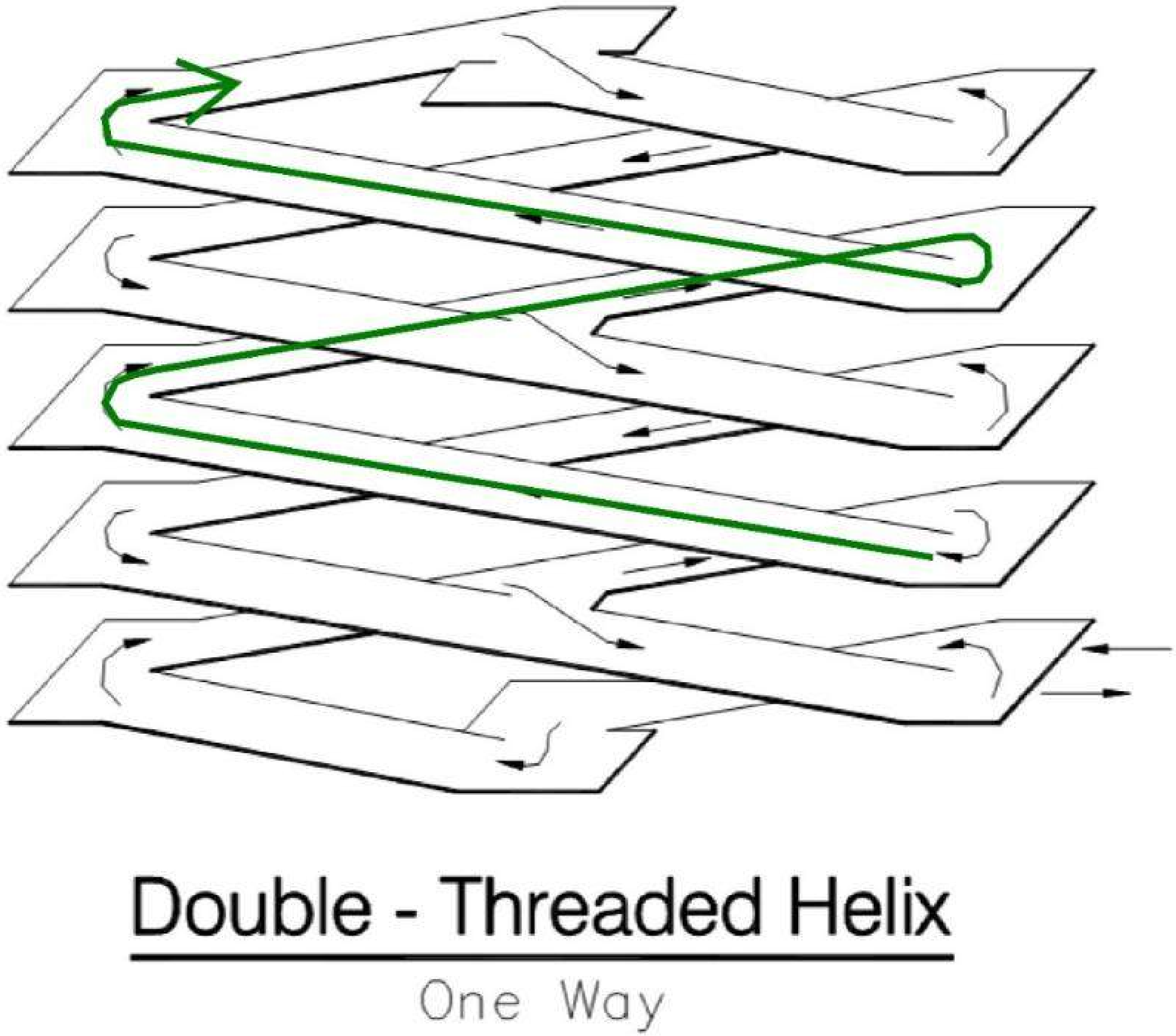
Single - Threaded Helix

Two Way

CIRCULATION

Double-Threaded Helix

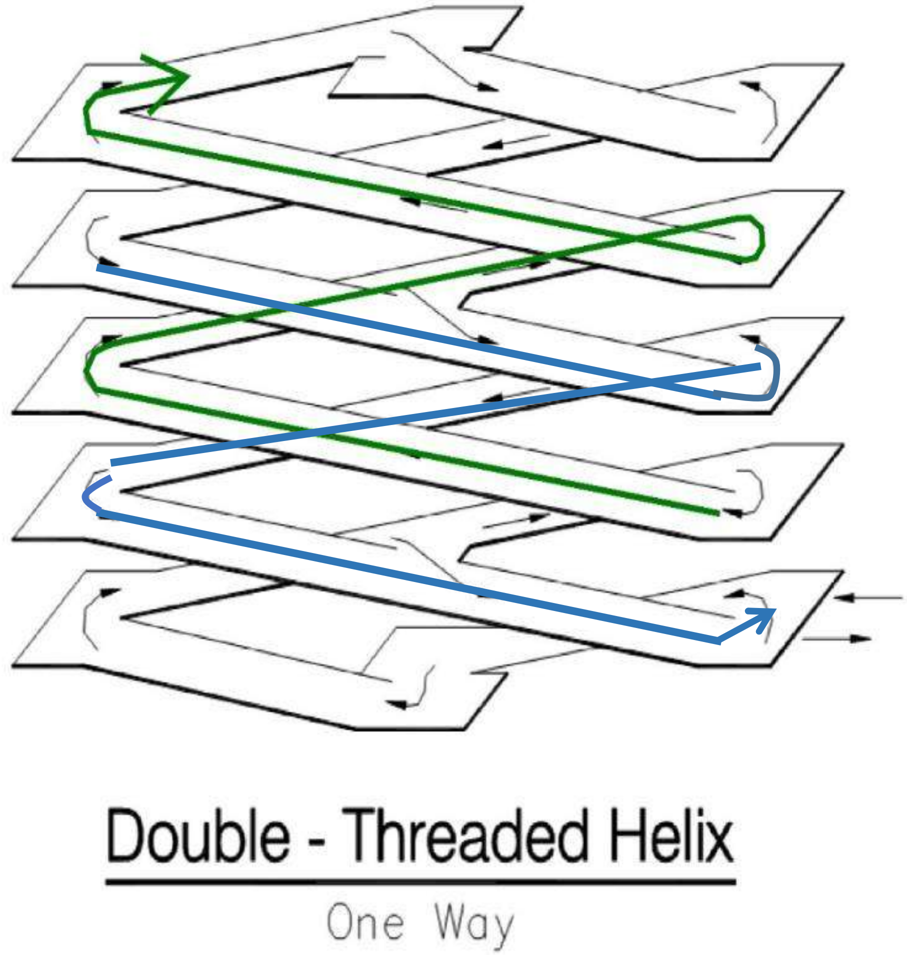
- Goes up **two** stories for each 360 degrees of revolution



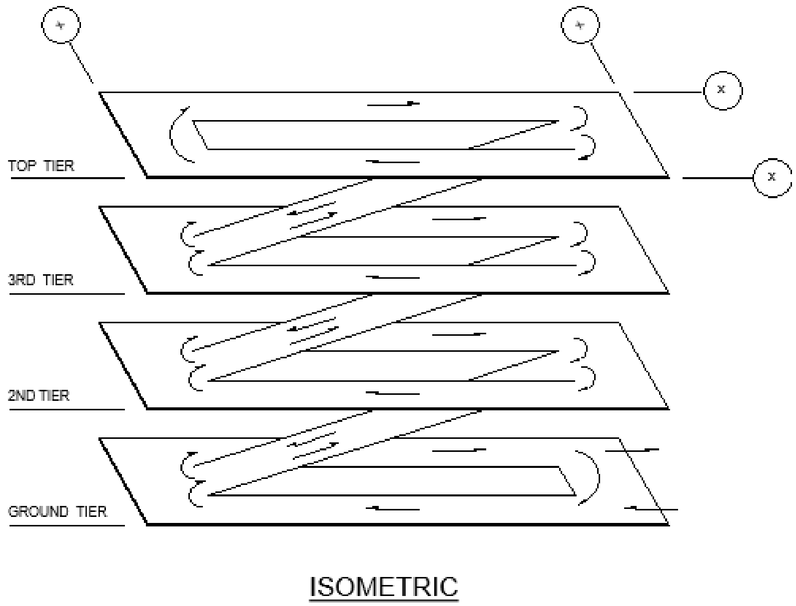
CIRCULATION

Double-Threaded Helix

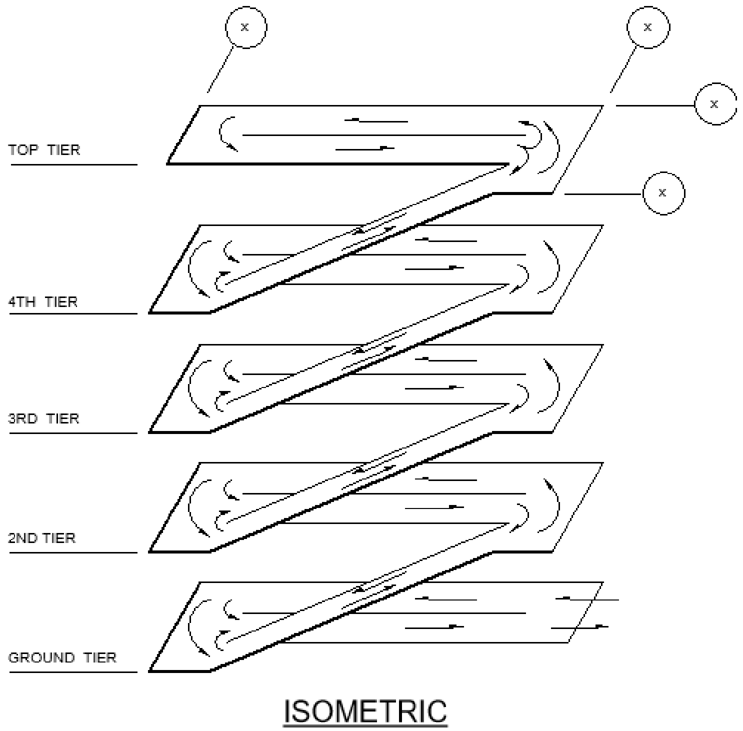
- Two threads intertwined in one footprint



OTHER COMMON CONFIGURATIONS



Good for 4-5 stories, simple facilities

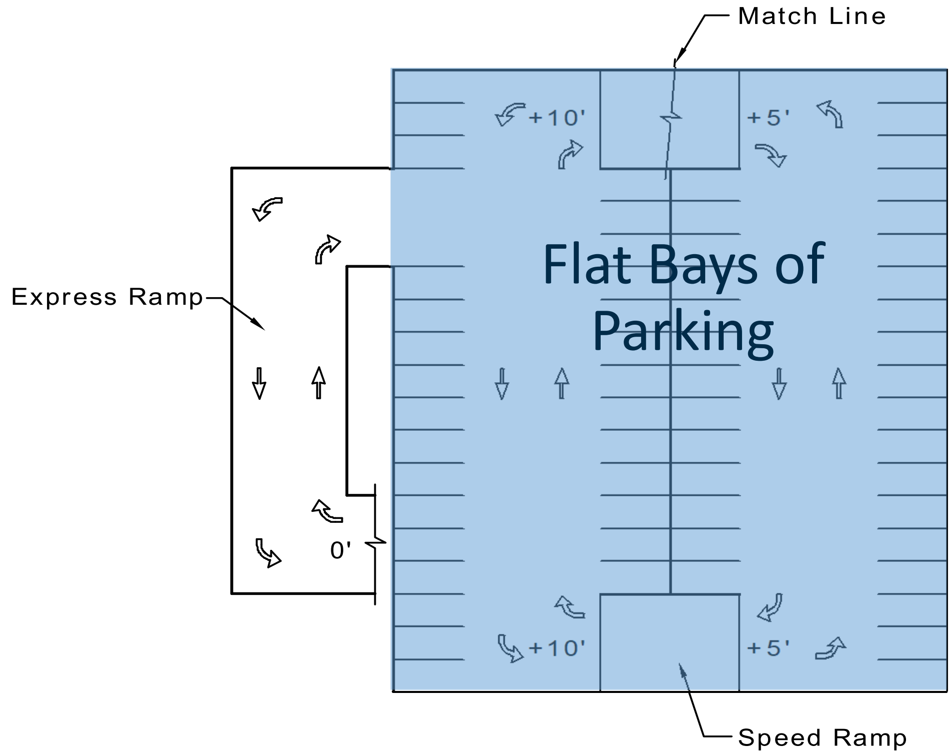


Provides more contiguous “flat” bays for pedestrians

NON-PARKING (AKA EXPRESS RAMPS)

- **Express ramp:** a ramp without parking along its length that provides circulation between one or more parking tiers
- **Speed ramp:** a ramp between two parking bays that are 5’ or less different in elevation. Usually located at a crossover or turning bay

Good for high-turnover, event type facilities



Ramps

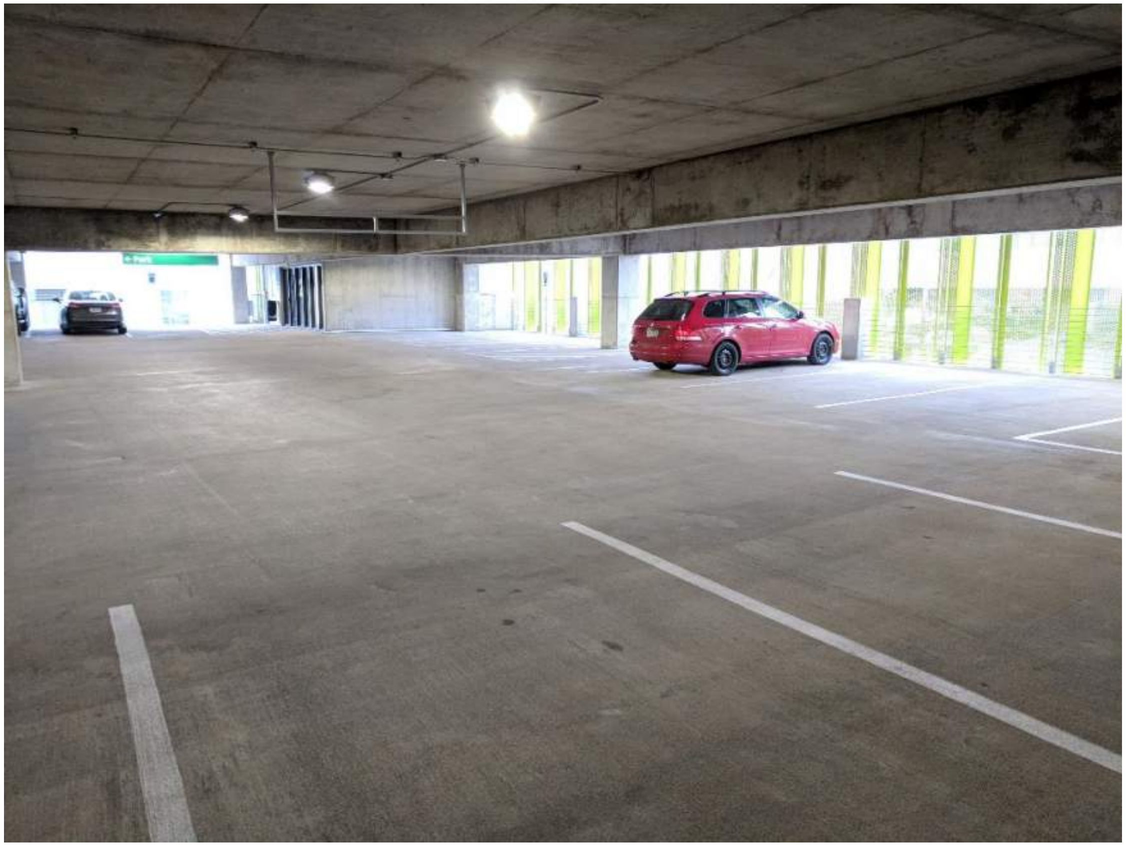
FUNCTIONAL DESIGN SUMMARY

- 85th percentile vehicle size used for sizing parking geometrics
  - Vehicle sales trends monitored
- Use a Level of Service approach to parking geometrics
- Understand your users:
  - long term parking vs. short term parking
  - frequent users verses infrequent users
- Ramping system must balance flow capacity, efficiency, and user convenience
- Wayfinding: sound Functional Design solves much more than signage!

SO NOW TO STRUCTURE!

The Devil is in the Details

- Durability provisions
- Drainage & Slopes
- Vehicle Guards
- Vehicle Weight



BUILDING CODE PROVISIONS RELATED TO PARKING

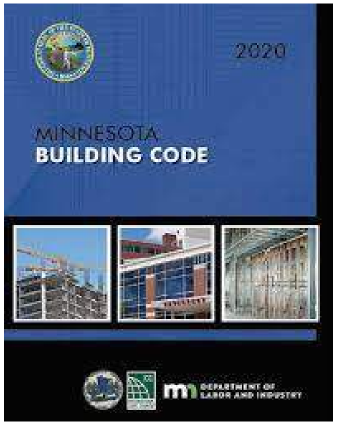
- **Select** building code provisions to be aware of in Minnesota (generally follows for WI, SD, ND, NE, IA)
- MN Rules requires protection of reinforcing steel

  1305.1904 SECTION 1904, DURABILITY REQUIREMENTS.
  IBC section 1904.3 is amended to read as follows:

  1904.3 Corrosion protection. Where bonded reinforcing and pre-stressing steel is located in concrete assigned to Exposure Class F3 or Exposure Class C2, the steel shall be protected from corrosion by one of the following methods:

  1. impermeable barrier;
  2. epoxy coating in accordance with ACI 318; or
  3. hot dipped galvanizing in accordance with ACI 318.

- Garage Slabs are generally Exposure Class F3, S0, W2, C2
  - w/cm <0.40 (F3)
  - f’c >5,000 psi (F3)
  - 6% air for ¾” aggregate (F3)*
  - Cannot be ASR/Alkali Carbonate reactive
  - Limits on chloride (C2): 0.15% for RC / 0.06% for prestress



**ACI 318-19 § 19.3.3.6 allows a 1% reduction for f’c>5,000, but not advised for design.*

SLAB COVER REQUIREMENTS

ACI 362.1R-12:

PT Slabs top 1.5”, bottom 0.75”

PC Slabs top and bottom 1.5”

In the Midwest it’s advisable to provide additional protection beyond minimums – **2 in top recc.**

318-19 Minimums

RC Tbl 20.5.1.3.1: slabs top & bottom = 1.5” (2” d_b>#6)

PT Tbl 20.5.1.3.2 slab top = 1.5” (exposed)

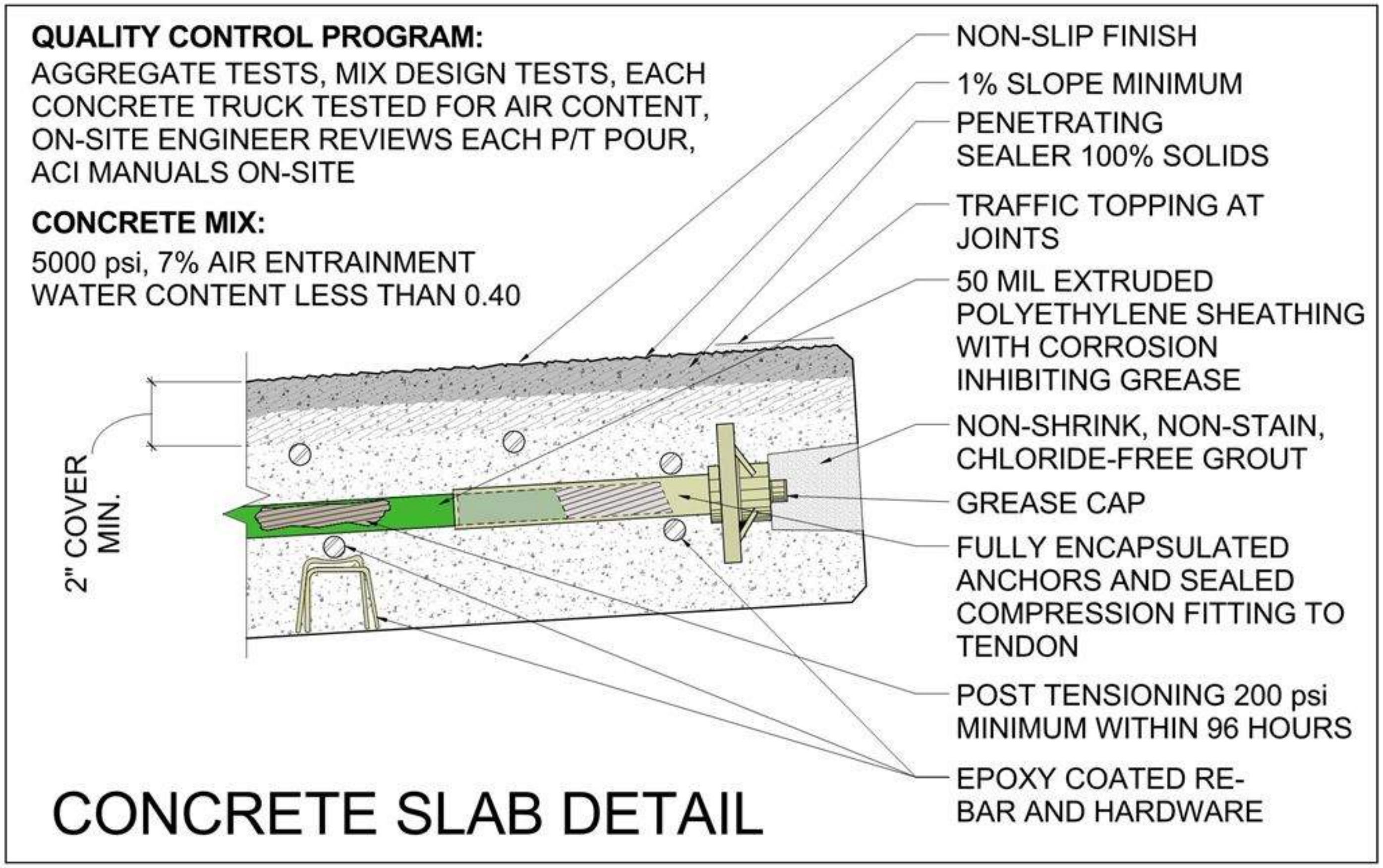
bottom = 0.75 (not exposed)*

PC Tbl 20.5.1.3.3 slab top & bottom* = 1.25” (exposed, 1.5” d_b>#6)

**Note R20.5.1.1 notes that slab soffits may or may not be exposed depending upon condensation or direct leakage conditions.*

DURABILITY RECOMMENDATIONS

An example of robust, highly durable slab design



DRAINAGE

- All vehicle floors should be designed to have at least 1.5% slope in any direction
- Flow should be directed away from stairs and Expansion Joints
- The construction documents should provide **high-point and low-point elevations** to depict the required drainage pattern and drain locations. All parking floor slabs should be designed so water flows to the drains without water ponding.
- **Similar to joist bearing elevations, the SE has an important role in influencing the drainage**

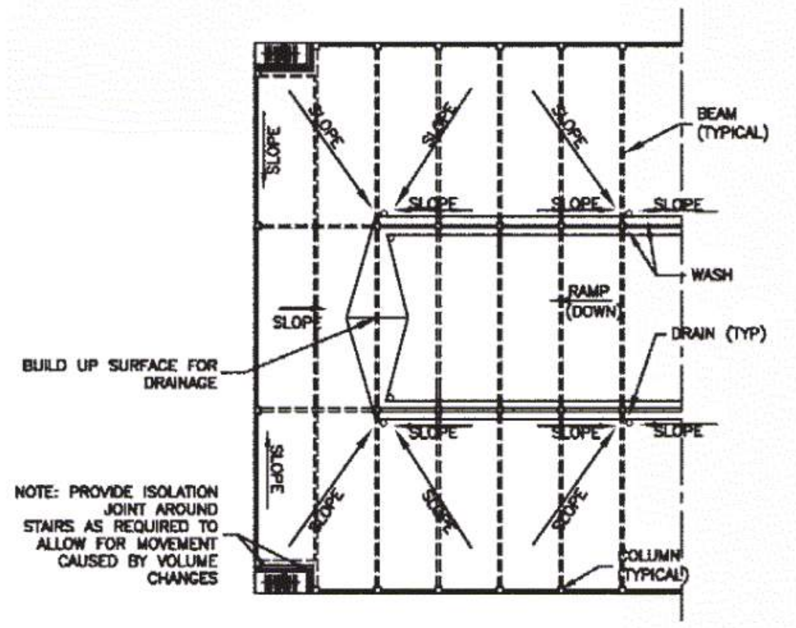


Fig. 6.2a—Schematic of post-tensioned one-way slab and beams system.

ACI 362.1R-12

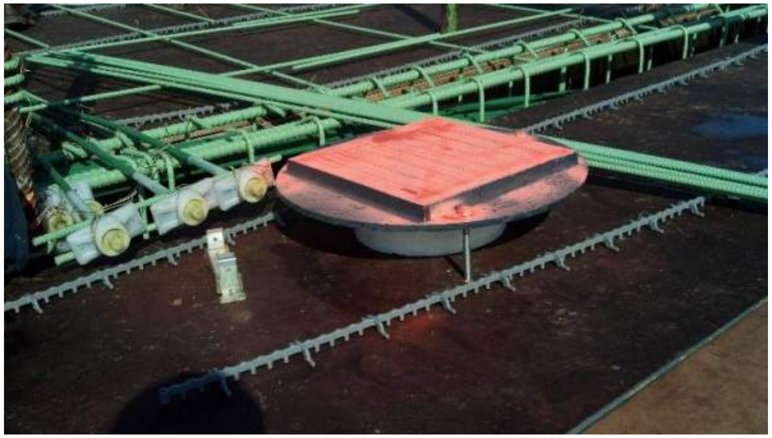
DRAINAGE – DON'T

Route water across sensitive areas

Expansion Joints will fail

Assume someone else is designing it

DRAINAGE – PLEASE DO



Ensure large fixtures are provided

Provide routes for plumbing – avoid going through slabs!

VEHICLE BARRIERS

VEHICLE BARRIERS

VEHICLE BARRIERS

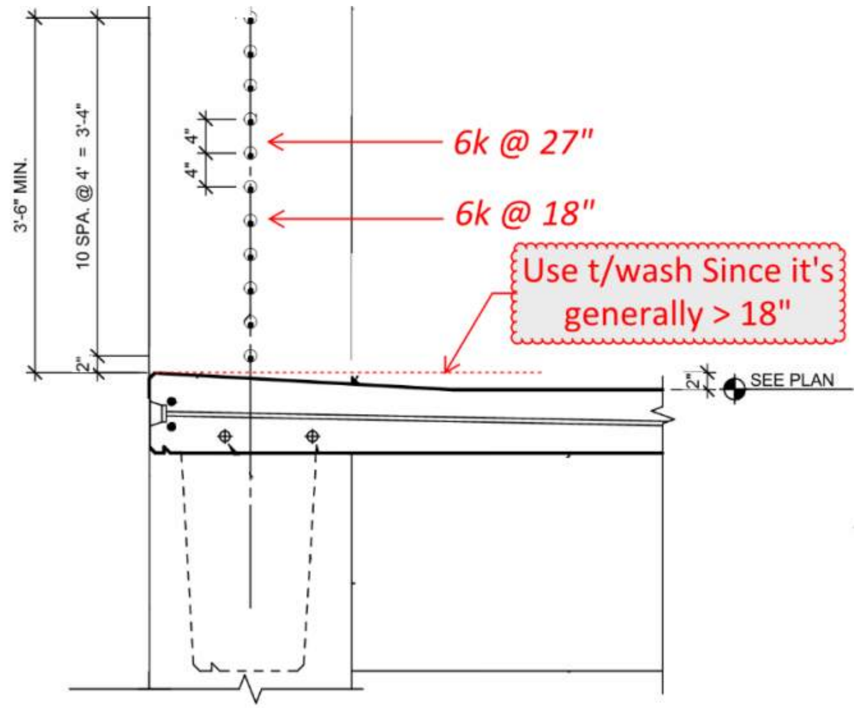
VEHICLE BARRIERS

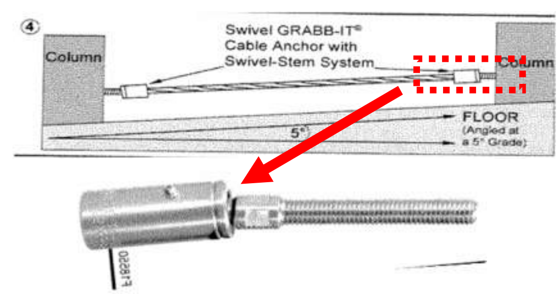
It’s a life safety system and needs to be designed

Concrete walls aren’t all created equal

Barrier cables are a great (better) system IF:

1. the building frame can develop the reactions and
2. The anchorage can develop the forces
3. The lateral displacement doesn’t impact façade materials





A trick! They make swivel anchors for ramps

GUARDS AND VEHICLE BARRIERS

Non-compliant Example

- Upturned beam provides a raised platform that does not meet the 42” rail height
- Provides a great ledge for some to unsafely climb upon

VEHICLE WEIGHTS

So, are EVs going to crush garages?

…likely not.

Very few heavy EVs are being sold

…In 2022 854 Hummer EVs were sold

…0.000656% of vehicles sold

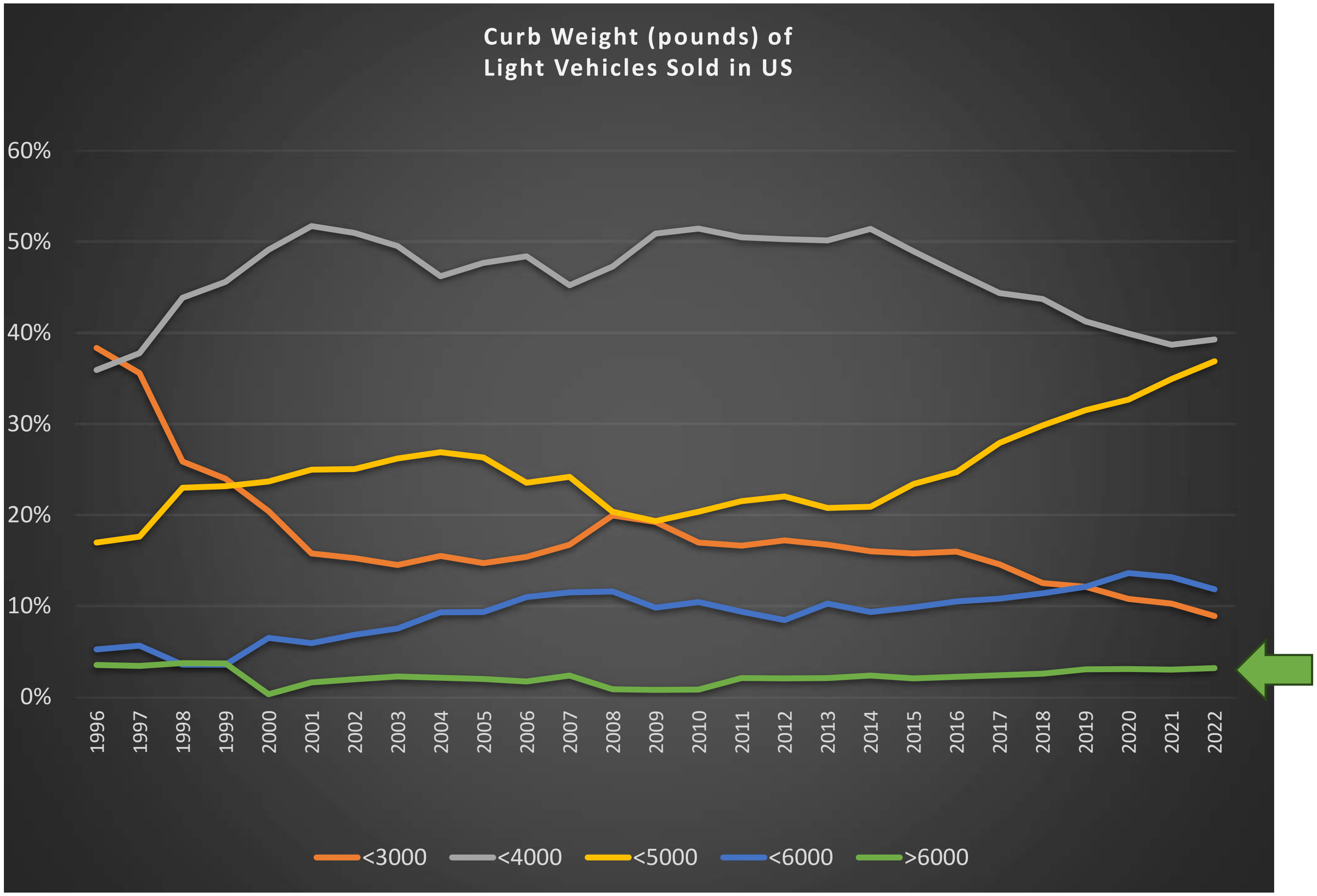
VEHICLE WEIGHTS

Are cars getting heavier?

YES, they are! BUT…

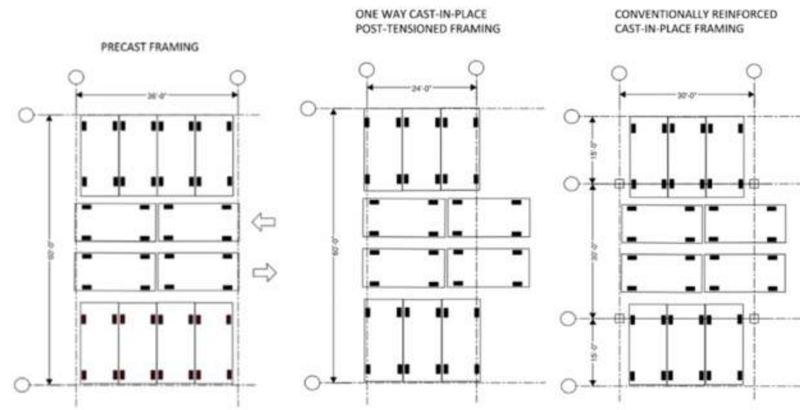
But on the top end curb weight of vehicles >6kip has held steady since 1996

Working with ASCE 7 on this…



WEIGHTS OF ELECTRIC VEHICLES

- Walker Studied weights of all EVs, PHEVs and ICE vehicles since 2011 to check LL*
- Determined the 85th DV for weights
  - Tesla Model S has curb wt of 4,710 lbs
  - GVWR of 6,660lbs in drive lanes
  - Loaded w/cargo in stalls at 5,610 lbs



LL = 40psf appears adequate still, Even for EVs

	Total Load (lbs)	Area (SF)	Live Load (PSF)
Precast Framing (36’ x 60’ Bay)	71,532	2,160	**33.14**
Cast-in-Place Post-Tensioned Framing (24’ x 60’ Bay)	53,649	1,440	**37.26**
Conventionally Reinforced Concrete with 30’ x 30’ Bay	26,644	900	**29.60**
Conventionally Reinforced Concrete with 15’ x 30’ Bay	16,833	450	**37.41**
Conventionally Reinforced Concrete with 30’ x 60’ Bay	60,310	1,800	**33.51**
Steel Beams and Column with P/C double tees	71,532	2,160	**33.14**
Steel beams and columns with a cast-in-place post-tensioned slab	53,649	1,440	**37.26**

*Similar to analyses of Y.K. Wen and G.L. Yeo (2001); Smith and Chrest (2002)


Objects in mirror are
closer than they appear
@justbinsdisposal

DETERIORATION PROCESS

Most deterioration is either

- Corrosion induced
- Freeze-thaw induced
- Volume change

Other deterioration mechanisms also exist, but not as prevalent

- Chemical
- Alkali-aggregate reactivity

CORROSION INDUCED DETERIORATION PROCESS

MOISTURE/ CHLORIDE PENETRATION

↓

REINFORCING STEELS CORRODES

↓

DELAMINATION

↓

SPALL

FREEZE-THAW INDUCED DETERIORATION PROCESS

MOISTURE SATURATES CONCRETE

↓

WATER FREEZES/ VOLUME CHANGES

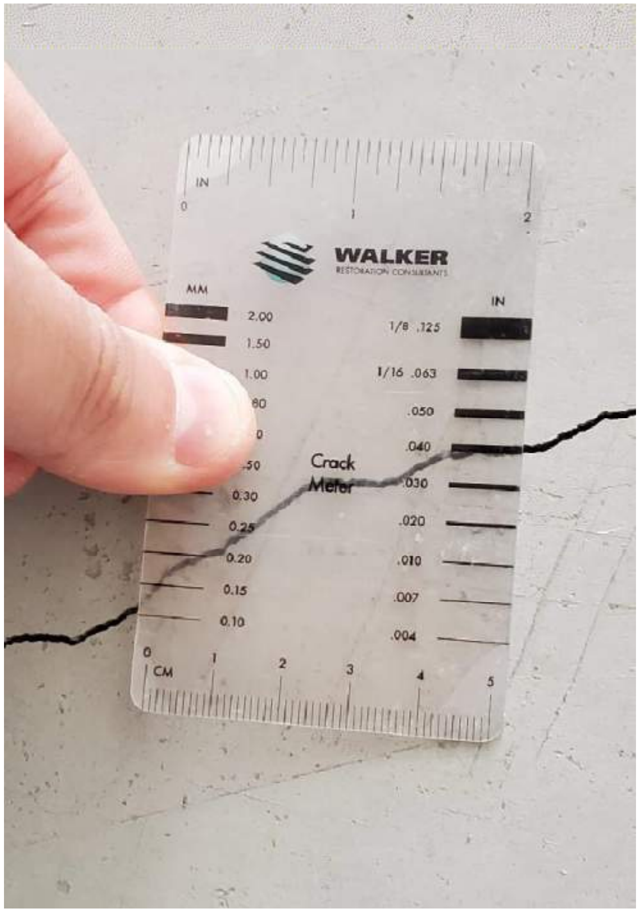
↓

SCALING, CONCRETE DETERIORATION

DURABILITY OF PARKING STRUCTURES

Focus on four goals:

- Control the cracking
- Prevent deicing salt entry
- Protect reinforcing steel from coming in contact with deicing salts
- Maintenance



DURABILITY MUSTS

Good Design Includes:

- Design and detailing to minimize cracking
- Adequate drainage
- Specify Great Concrete mixes
- Finishing and curing
- Surface sealers and joint sealants
- Epoxy-coated reinforcing steel
- Stainless steel / galvanizing connections
- Proper concrete cover
- Encapsulated PT tendons
- Corrosion inhibitors


EXIT

THANK YOU !