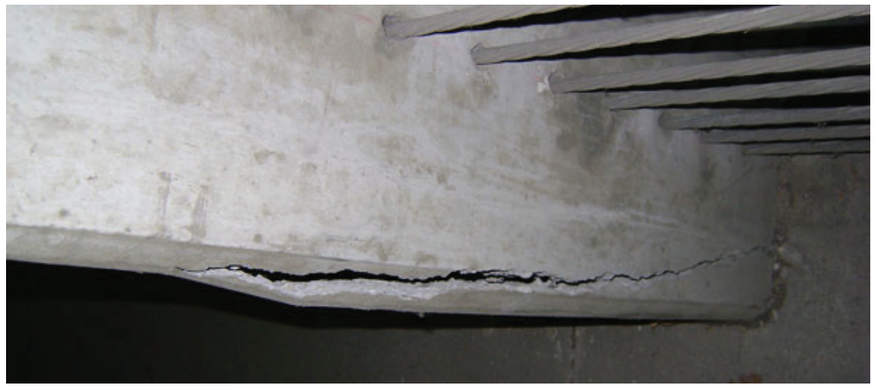
STRUCTURAL



Cracking due to poor structural design

Moisture damage

Chloride corroded reinforcing steel

Structural Considerations

The structural behavior of a parking structure is significantly different than that of a building. Understanding those differences, and the resulting limitations, is critical to the design of a parking structure. The Iowa climate also introduces a wide variety of variables that must be accounted for in the design.

Typically, the structural design must account for the dead, live, snow, wind, and seismic loads. Other loads that must be calculated for in the parking structure are vehicular wheel loads and impact loads. The design must also consider and evaluate the vibratory nature of these loads.

Parking structures are exposed to daily and seasonal ambient temperature variations, resulting in significant movement of the structure. Restraining this movement can cause the floors, beams and columns to crack.
Temperature fluctuation is not the only weather related factor that must be accounted for in the design. All levels of a parking structure are exposed to snow, ice and rain. Design of the structure must accommodate the removal of this precipitation as proper drainage and maintenance are critical to the life of the structure. Other considerations include chlorides used to de-ice city streets collect on the underside of cars and eventually may be deposited on the floor of the structure. If the chlorides come in to contact with concrete reinforcing corrosion will be accelerated significantly.

Increasing Durability

The harsh Iowa climate presents many challenges in parking structure design. Fortunately, numerous strategies can be implemented to improve durability and increase the life span of the structure.

Perhaps the most significant contributor to structure durability is following good concrete installation practices. A low water/cement ratio, proper concrete finishing, and excellent concrete curing will extend the durability of a parking structure at a minimal cost increase. Typically, a water/cement ratio of 0.44 or less is used depending on the specified concrete strength. Concrete should be placed in its final position, struck, floated, and broomed. The addition of water to improve finishing operations is not allowed. Concrete must be allowed to cure a minimum of five days. Utilizing a wet cure is the preferred method. Low ambient temperatures may dictate the use of a dissipating curing compound.

Historic data indicates that providing epoxy coated reinforcing steel in the columns increases their durability. Selective use of epoxy coated reinforcing steel and adequate concrete cover over the reinforcing will help reduce corrosion of the steel. For all structural components exposed to deicers, a minimum of a two inch cover is recommended. Epoxy coated reinforcing steel is typically provided in the beams and slabs.

Providing adequate floor slopes and floor drains helps facilitate proper drainage, which increases the life of the structure. Using large floor drains, such as twelve inches by twelve inches, facilitates removal of water from the slab. During ramp design a minimum of 1 ½% slope for slab drainage is utilized. In precast construction, the design must take into account the double-tee camber when calculating the slab slope. Typically a varying flange thickness is used to overcome any camber issues.

Locally, most concrete mixes utilize fly ash as part of the cementitious material. Typical levels range from fifteen to twenty percent by weight of cementitious materials. Chloride ion penetrability testing is performed to establish proper levels. Corrosion inhibitor is a concrete admixture that chemically reacts with the embedded reinforcing steel, producing a barrier that prevents chloride penetration. This admixture is frequently used with good results. The structural engineer will typically work with the manufacturer to ensure correct dosages are being used Ames's environment.

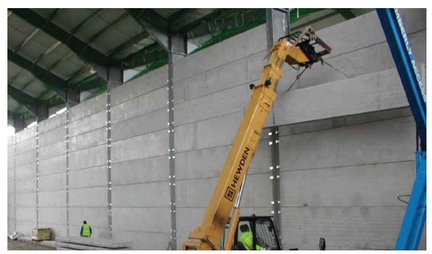
Concrete penetrating sealers are intended to reduce moisture and salt penetration of the concrete surface. Most owners choose to make the initial investment of utilizing a penetrating sealer. This is due to the sealer extending the life of their parking structure. Membrane coatings are liquid applied materials that form a seamless barrier to protect the concrete. Their material properties allow for certain amounts of elongation, abrasion resistance, and chemical resistance. Due to the product's cost, it is most often used only in selective areas such as top floor of the parking structure.

Historically, there have been three types of parking structures built in Iowa. Due to the corrosive nature of the Iowa environment and its negative affect on a steel beam structure when incorporated in a parking facility only two options are being considered. These options are cast-in-place, post tensioned concrete; and precast pre-stressed concrete

Cast-in-place, post tensioned concrete

The Cast-in-place [CIP], post tensioned system offers several advantages for use in parking structures. This system can accommodate many complex structural geometry configurations. Another advantage is the induced compressive stress minimizes tension in the concrete, resulting in fewer tension cracks. This system is also very durable when good concrete practices such as low water/cement ratio, efficient placement, proper finishing, and proper curing are utilized. Poured monolithically, this system has few construction joints. This is advantageous because construction joints are potential sources of moisture intrusion and can become an ongoing maintenance issue.

One limitation of using the cast-in-place, post tensioned system is the initial cost is typically higher than that of a precast prestress system. Another disadvantage is the placement and stressing of tendons requires iron workers who are experienced with this type of system. The cast-in-place system is susceptible to delays from inclement weather. In addition, supplemental heat and protection may be required during cold weather. Finally, the forming, shoring, and re-shoring of each floor during construction takes considerable time. This, in turn, slows down construction.



Precast Prestressed Concrete Systems

This option is our recommended structural system for your facility. The precast pre-stressed concrete system offers several advantages for use in constructing parking structures. The first is early fabrication of pieces can occur off site and deliveries can be scheduled for quick erection. Also, the system is not susceptible to weather delays because of off site fabrication of pieces. Thirdly, induced compressive stress minimizes tension in the concrete, resulting in fewer tension cracks. Perimeter beams can be used as the exterior façade and barrier rail system. Precast members generally have a high quality finish using durable concrete. Typically, the initial cost of precast prestress parking structures is less than a cast-in-place, post tensioned system.

One limitation of using a precast pre-stressed system is because the system consists of many individual pieces, there are a significant number of joints in the final product. Each joint represents a potential maintenance item. Another disadvantage is multiple connections of the precast pieces which are potential maintenance areas. In addition, connections can affect the aesthetics of the structure. Third, camber in the double-tee's caused by the prestress strands can affect the proper drainage of the parking structure. Finally, double-tee toppings are not pre-stressed and offer limited crack control due to tension.

Maintenance

All parking structures, regardless of construction type, require maintenance. Ordinary housekeeping such as cleaning deck surfaces, changing light bulbs, and oiling ventilation fans are only a small portion of the overall maintenance required. Three specific categories to consider are housekeeping, operations, and operator maintenance; annual general maintenance and repair; and periodic repairs, protection, and improvements.

Annual housekeeping, operations, and operating maintenance will be based on specific operation requirements. Historically these have proven to cost approximately $350-$450 per space. Depending on the condition and type of structural system, annual general maintenance and repairs will cost approximately $35-$50 per space.

Periodic repairs, protection, and improvements will be lower during the first ten years of life. The cost will increase to accommodate improvements necessary as a facility ages. For a new structure, this item may range from $70-$100 per space, per year, for the first ten years. After that, the cost can increase 50-75% per year. These items depend heavily on the amount of ongoing maintenance that is performed throughout the structure's lifespan.

Certain construction types require specific maintenance needs as well. Precast structures may require more intensive maintenance every seven to ten years, whereas cast-in-place structures require one every twenty years. The maintenance cycle is a factor that must be considered when selecting a certain structural type keeping in mind that the typical life cycle for either structure is fifty years.

Assumptions

- A smaller sized sweeper could be hired to clean the deck throughout the year as it is not cost prohibitive to raise the structure an additional 5'-7'. Providing the required clear height of 12'-14' at the lower level allowing the City the use of a standard sweeper to clean the garage is not necessary.
- Snow removal will be done with a pickup truck and skid-steer maintaining the standard vehicle required clearance of 7'-0". A snow gate system on the upper deck may be provided above the one of the drive aisles to allow for the snow to be pushed off the edge into a dump truck below and taken off site.

MAINTENANCE COSTS	Number of Stalls*	Annual Housekeeping, Operations, and Operator Maintenance	Annual General Maintenance and Repairs		Annual Periodic Repairs, Protection, and Improvements (Initial 10 Years)	Annual Periodic Repairs, Protection, and Improvements (After 10 Years)	
			Cast-in-place	Precast		Cast-in-place	Precast
Cost Per Stall		$350 - $450	$35	$50	$70 - $100	$105	$175
Concept A	**400**	**$140,000 - $180,000**	**$14,000**	**$20,000**	**$28,000 - $40,000**	**$42,000**	**$70,000**
Concept B Phase I	212	$74,200 - $95,400	$7,420	$10,600	$14,840 - $21,200	$22,260	$37,100
Concept B Phase II	188	$65,800 - $84,600	$6,580	$9,400	$13,160 - $18,800	$19,740	$32,900
Concept B complete	**400**	**$140,000 - $180,000**	**$14,000**	**$20,000**	**$28,000 - $40,000**	**$42,000**	**$70,000**
Concept C	**346**	**$121,100 - $155,700**	**$12,110**	**$17,300**	**$24,220 - $34,600**	**$36,330**	**$60,550**

**Total number of available spaces in any of the conept options assumes a variance to the commerical space requirement [ORD. NO. 3822, 3-8-05]*

Annual Housekeeping, Operations, and Operator Maintenance

Cleaning	*Sweeping*	*Washing*
Doors & Hardware	*Lighting*	*Elevator*
Fire Protection	*Signage*	*Landscaping*
Snow Removal & Deicing	*Parking Equipment*	*Painting*
Mechanical, Electrical, & Plumbing		

Annual General Maintenance and Repairs

Concrete Repairs	*Masonry Repairs*	*Painting*
Sealants/Expansion Joints	*Deck Coating*	*Graffiti Removal*
General Electrical Repairs	*HVAC*	*Plumbing*
Light Fixture Repair / Replacement		

Annual Periodic Repairs, Protection, and Improvements

Replacing / repairing damage to waterproofing or structural elements

Initial 10 Years	***After 10 Years***
Replace Electrical Signage	*Painting of Surfaces*
Replace Parking Equipment	*Replace Elevators*
	Replace Standard Signage
	Electrical & Mechanical Systems