Mission: More than 17% of Berkeley’s 10.5 square miles of land surface area is paved over by streets and sidewalks “hardscaped” by impervious materials. This has enormous climate impact due to the effects on surface water runoff quantity and quality, surface heat retention and reflection, and the overall carbon footprint of the City’s purchased raw materials. The manner in which the City of Berkeley constructs and maintains the city’s streets and sidewalks can mitigate these effects.

The Paving Work Group is striving to find and recommend integrated solutions that can be implemented to help attain the goals of the Climate Action Plan by addressing multiple demands on City’s infrastructure that are environmentally sustainable, economically efficient, and effective in the long term. The Commission’s findings will enable the City Council to amend the Street Rehabilitation and Repair Policy, Resolution No. 55,384-N.S., last approved by the Council in 1990, and to proceed with specific trials for testing integrated environmentally sustainable paving solutions.

PREFACE:
Preface: The Public Works Commission’s Paving Work Group has researched Permeable Pavers as a means of managing and resolving issues associated with the following:

- Storm water impact and flooding
- Traffic calming - public safety
- Street durability and cost effectiveness
- Carbon footprint and the environmental sustainability of paving materials
- Sidewalk repair expense due to tree root heaving on cement sidewalks
- Heavy metal impact from streets that wash into gutters/storm drains and then into SF Bay
- Urban Design and Federal requirements

Integrated Pavement Alternatives: Permeable pavers

While the Public Works Commission strives to find integrated solutions to address the multiple demands on the City’s infrastructure, we are conscious of the harmful effects that local solutions could have on non-Berkeley residents. Moving our carbon footprint to someone else’s community is not a sustainable solution.

Our communications with city engineers and industry representatives have explored the potential to solve multiple climate issues through the use of Permeable Interlocking Concrete Pavers (PICPs). This technology, widely used in Europe, is being embraced by many cities in the US. We have talked with city engineers in Portland, OR; Warrenville, IL; Oakland, CA; and Moline, IL. All are very positive about their implementation of these materials. PICPs offer an integrated approach to many of the issues we face in streetscape planning.

Summary of beneficial attributes of PICPs:

- Provide a durable, semi-smooth surface (not slippery like asphalt when wet)
- Create long term cost benefits; initial cost is 50-60% greater, but PICPs are more durable, lasting 3-5 times longer (50-100 year lifespan)
- Reduce carbon footprint - there are 783 metric tons of CO₂ produced with current paving materials
- Limits peak stormwater discharge and improves water quality of any runoff
- Create the potential to mitigate street sweeping requirements and improve runoff water quality
- Decrease sidewalk cement heaving
- Reduce solar heat gain because of light surface color and permeable material
- Enable traffic calming
- Provide aesthetic improvements

The Regional Water Quality Control Board is very interested in permeable technology; we should explore funding collaboration for a demonstration project.
ADA requirements: PICPs can be dimensioned with a void area of 11mm or less with a 15mm angled top separation or chamfer that provides a smooth surface and meets ADA requirements of 13 mm or (.511 inch) maximum space between pavers.

Concrete Pavers also produce less vibration than flowed cement:
Study on Vibration Exposure of Individuals Using Wheelchairs over Concrete Paver Surfaces.

Funding provided by:
- VA Rehabilitation Research and Development Service, Veterans Health Administration, U.S. Department of Veterans Affairs (F2181C)
- The U.S. Department of Education, National Institute on Disability and Rehabilitation Research (NIDRR) Rehabilitation Engineering Research Center on Wheeled Mobility (H133E990001), a National Foundation Graduate Research Fellowship
- A consortium of the Interlocking Concrete Pavement Institute (ICPI), Brick Industry Association (BIA) and the National Concrete Masonry Association (NCMA).

Conclusions:
“Based on the manual and power wheelchair results of this study, use of selected [interlocking concrete pavers] would be acceptable for any route traveled by individuals using wheelchair. The results are as good as, and in some cases better, than that of a standard sidewalk surface. A bevel of less than or equal to 6mm must be used for routes used by individuals using wheelchairs. Furthermore, a 90 degree herringbone pattern is preferred over the 45 degree pattern, while the 90 degree herringbone pattern is required for the 6mm beveled pavers to maintain safe levels of vibration exposure”.
## Benefits to the City of Berkeley:

<table>
<thead>
<tr>
<th>Reason for Improvement</th>
<th>Root Cause</th>
<th>Mitigation Focus</th>
<th>Benefit to City</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve long term durability of street paving materials</td>
<td>Clay soil seeps up into the stones and gravel base of older streets, causing instability. This leads to cracks, allowing storm water to create potholes</td>
<td>PICPs will allow for up to a 50-100 year life cycle for properly constructed street vs. less than 17 years for asphalt (shorter on major or collector streets).</td>
<td>PICP construction is <strong>45% to 60% more expensive</strong> on like-to-like construction (reconstructed street). However, <strong>durability is nearly 3-5x longer (50-100 year life cycle)</strong>.</td>
</tr>
<tr>
<td>Reduce storm water street flooding</td>
<td>Hardscaped streets force all water into storm drains in short time intervals</td>
<td>PICPs will slow the velocity of water into storm drains by absorbing water into gravel base and sub-base before reaching storm drains, thus reducing downstream flooding</td>
<td>Help reduce the need to build larger storm drains ( $80M total cost from past estimates but with a near term $11m capital budget and annual $1.3M expense budget)</td>
</tr>
<tr>
<td>Reduce the speed of traffic on city streets</td>
<td>Increased traffic volumes and pace of urban life have led to injuries and traffic deaths on our hardscaped city streets</td>
<td>PICP implementations in Portland, OR; Warrenville, IL; and the Netherlands have seen the reduction of traffic speed and increased overall driver and pedestrian awareness</td>
<td>Help <strong>reduce the average rate of speed from 30 MPH to 25 MPH</strong> without police enforcement costs</td>
</tr>
<tr>
<td>Reduce greenhouse gases by 80% by the year 2030.</td>
<td>Oil based asphalt adds to the increase of greenhouse gases through production and the need for constant repair - currently 783 metric tons of CO$_2$ are produced annually with current paving methods</td>
<td>PICPs will incrementally reduce greenhouse gases by using “green cement” that sequesters CO$_2$ into cement and “smog eating” titanium dioxide paver coatings - allowing for increased use of electrical vehicles. PICPs reduce surface heat gain through the use of light colored pavers and absorb heat through open space between pavers</td>
<td>Help meet City’s greenhouse goals by year 2030 and help reduce dependence on fossil fuels</td>
</tr>
<tr>
<td>Reduce sidewalk repair cost from tree roots heaving cement.</td>
<td>Hardscaping seals the surface. Tree roots which require water and air, must break through, entering sanitary and storm drains, lifting asphalt and cement</td>
<td>PICPs enable roots to sink vertically down and still drink and breath</td>
<td>Help reduce $778K annual capital budget associated with sidewalk repair costs (mostly associated with tree root break-through)</td>
</tr>
<tr>
<td>Reduce impact of storm water runoff into San Francisco Bay</td>
<td>50% of heavy metals in Bay originates from hardscaped streets according SF Bay RWQCB</td>
<td>PICP implementation will help trap and filter heavy metals in base and sub base of PICP constructed streets</td>
<td>Reduce street sweeping frequency/costs (SF Bay RWQCB proposes an increase to weekly sweeping to mitigate heavy metal issue - clean cities budget is $3.5m annually)</td>
</tr>
<tr>
<td>Improve charm and character of our urban streetscape, maintaining ADA compliance</td>
<td>Oil based asphalt streets do not create the aesthetic that is associated in the public’s mind with great urban environments or cityscapes</td>
<td>Initial focus will be on gateway and redevelopment projects that will enhance our reputation as an innovative ADA compliant city</td>
<td>Enhance the economic value of the City’s current development plans</td>
</tr>
</tbody>
</table>
Proposed PICP trial streets (done in consultation with Public Works engineering staff)

**PICP Paving Plan Selection Criteria**

<table>
<thead>
<tr>
<th>Current PW Reconstruct Plan</th>
<th>Street Name</th>
<th>From</th>
<th>To</th>
<th>Class</th>
<th>Treatment Planned</th>
<th>District</th>
<th>P</th>
<th>Mileage</th>
<th>Attribute(s) to Trial</th>
<th>Street Rank order</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012 Bancroft Way</td>
<td>Telegraph</td>
<td>Shattuck</td>
<td>C</td>
<td>Overlay</td>
<td>7</td>
<td>B</td>
<td>.56</td>
<td>D,G,T,WQ</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2010 Addison</td>
<td>Milvia</td>
<td>Shattuck</td>
<td>C</td>
<td>NP</td>
<td>4</td>
<td>D</td>
<td>.12</td>
<td>D,G,T,WQ</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2011 Marin</td>
<td>Alameda</td>
<td>West city Limit</td>
<td>A</td>
<td>Overlay</td>
<td>5</td>
<td>B</td>
<td>.31</td>
<td>D,G,T,WQ</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>2011 University</td>
<td>Milvia</td>
<td>Oxford</td>
<td>A</td>
<td>Overlay</td>
<td>4</td>
<td>C</td>
<td>.26</td>
<td>D,G,T,WQ</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>2013 Sacramento (NB&amp;SB)</td>
<td>Dwight Way</td>
<td>Oregon St</td>
<td>A</td>
<td>Reconstruct</td>
<td>2, 3</td>
<td>C</td>
<td>.88</td>
<td>D,G,T,WQ</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>2011 4th University</td>
<td>Channing Way</td>
<td>R</td>
<td>Reconstruct</td>
<td>2</td>
<td>B</td>
<td>.43</td>
<td>D,G,SF,WQ</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011 Webster</td>
<td>Deakin</td>
<td>Colby</td>
<td>R</td>
<td>Reconstruct</td>
<td>7</td>
<td>D</td>
<td>.25</td>
<td>D,G,T,WQ</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>NA Center</td>
<td>Milvia</td>
<td>Oxford</td>
<td>C</td>
<td>None</td>
<td>4</td>
<td>C</td>
<td>.26</td>
<td>D,G,T,WQ</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

**Class**: Arterials (A) Collectors (C) Residential (R)

**Treatment**: Reconstruct, Overlay or Slurry

“P”: Denotes presence of (A) Bicycle Boulevard, (B) Bicycle Route, (C) Bus Route, (D) None

**Attribute**: (D) Durability, (G) Greenhouse gases, (T) Traffic Calming, (SF) Storm Drain Flooding, (WQ) Storm water run-off - pollutant filtering.
Permeable Interlocking Concrete Pavers (PICP)

Pavers are **significantly more durable** than flowed cement. The Port of Oakland, paved with PICPs, has routine traffic flow of multiple containers—with up to 240 tons per load area. This is far more than is carried by even our most challenging city streets.

Berths 55/56 at the Port of Oakland utilize a record-breaking 39 acres of interlocking concrete pavement for container yards. The earth works in the right background (behind cranes) will see an additional 46 acres next year, soon to be another record breaker.
Other Cities are using these alternative paving solutions to oil based asphalt.

- PICPs provide a 50 year minimum life cycle for wear and durability.
- No sealant is required.
- The only routine maintenance requirement is annual street sweeping.
- Pavement can be removed and re-instated if access for utility structures or installation of new utilities is required.
- All pavers will meet ASTMC-936 and will be at least 8,000psi, with an absorption rate less than 5%.

Portland, OR - Mechanical installation equipment places the permeable pavers in the final laying pattern over the bedding course.
Permeable Interlocking Concrete Pavers (PICPs)

Portland, OR - Permeable pavers (PICPs) receive runoff into an open-grade aggregate base, or “drainage blanket,” that extends under the asphalt across the entire street. This boosts water storage and infiltration capacity.

Portland, OR - Deteriorated concrete curbs and driveway aprons were replaced. Existing storm drainage inlets and pipes were left in place for use as an overflow drain during heavy rainfall.
Warrenville, Illinois

The Warrenville City Council directed their Street Superintendent to trial Permeable Interlocking Pavers on a mile-long city Community Collector Street. He initially was opposed to the change, but is now an enthusiastic supporter even with their clay soil conditions. Resulting benefits are:

- Reduction or elimination of storm water run-off from pavement surface
- Filtration of rain water prior to entering sub drain storm sewer
- Storm water detention
- Elimination of road surface effects from the freeze and thaw winter cycle
- No surface water ponds
- Traffic calming
- Charm and character
- Acceptance by older generation (long time) residents
- Projected long-term cost benefits (compared to asphalt paving)

Collector street in Warrenville, IL
Current street sweepers will continue to be effective with PICPs, but frequency can be reduced. Use will meet all San Francisco Bay water requirements.

All paving materials have a carbon footprint – PICPs can lead to dramatic mitigations.
Working with a “Green Cement” producer to set up trials in Berkeley, we can contribute to the reduction of California CO₂ levels by helping to mitigate the City’s internal carbon producing activities. The carbon sequestered in green cement paving materials can play a significant part.

A cubic yard of normal Portland cement emits 250lbs of CO₂ in its production. Green cement, using the process under production at the Moss Landing cement plant and the PG&E Moss Landing power generation facility, sequesters 1250 lbs. of CO₂. This process captures the CO₂ from the unfiltered flue emissions of those facilities into the green cement for a net reduction of 1500 lbs of CO₂ per cubic yard.

Meeting Berkeley’s Climate Action Plan goals all departmental functions must be re-thought and re-engineered. Integrated paving technologies can provide a significant integrated climate action effect on the way Berkeley’s Public Works Department structures its purchases and organizes its ongoing paving activities.