Electrification of Roads: Infrastructural Aspect

1. Why ‘Electrification of Roads’

As an alternative solution, Electric Vehicles (EVs) have been given focus as a potential solution towards enhanced sustainability of the road transportation sector in the long term run. In this, due to the limitations of energy source technologies, recharging opportunities away from home have become a critical concern to achieve widespread demand for the use of EVs. The ‘Electrified Road’ (E-Road) infrastructure is defined as a transportation infrastructure that is able to “deliver the electrical power to charge EVs efficiently stationary or even in motion, using specific conductive or contactless charging solutions”. Within this definition, E-Road can serve as an ordinary road for vehicles driving on and at the same time delivering electrical energy to power EVs (refer in particular the EVs that use batteries). Being a near-field IPT technology, the Inductive Power Transfer (IPT) technology has shown good performance and is being studied actively as a contactless charging solution in a dynamic way.

- Opportunities for IPT technology:
  - Eliminate the battery limitations for EVs (cost and range);
  - More convenient and possibly safer than the conductive solution;
  - Lower energy cost than fossil fuel;
  - Integration renewable resources (wind, solar) into power grid.

2. How ‘E-Road’ work

**Inductive Power Transfer (IPT) System**

A typical IPT system usually consists of an on-board device installed under the vehicle’s chassis and an off-road power delivery device mounted inside the road surface. As illustrated in Figure 1, the off-road system that will be integrated into the road surface mainly has three parts:

1. The power provider supplies a DC output voltage by a rectifier;
2. A converter to achieve high output frequencies (normally between 20kHZ~100kHz), and combining with capacitances to achieve resonance and reduce the switching loss;
3. A transmitter consisting of coils, ferrite cores and backing plate, which is mutually coupled with the pick-up device.

**Integration of IPT system into road structure**

![FIGURE 1 Diagram of a typical static IPT system for BEVs](image)

**TABLE 1 A summary of potential methods for improving E-Road structural integrity**

<table>
<thead>
<tr>
<th>Method</th>
<th>Priorities</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt HMA overlay</td>
<td>Increased thickness</td>
<td>To reflect the energy by increasing the thickness of HMA overlay. Not applicable.</td>
</tr>
<tr>
<td>Reinforced HMA materials</td>
<td>To expand the pavement material and surface</td>
<td>Not applicable and not economical.</td>
</tr>
<tr>
<td>Open graded structure</td>
<td>Contains large interconnected asphalt and can relieve the stresses caused by FCC movements.</td>
<td>Performed well and reduces noise.</td>
</tr>
<tr>
<td>Surface seals</td>
<td>Be applied before the road surface to relieve the stress of patching or reconstruction is required.</td>
<td>Cost-effective and quick maintenance treatment method of repairing pavement.</td>
</tr>
<tr>
<td>Skim seals</td>
<td>Be applied in thin overlays (varies from 3 mm to 12 mm) to avoid permanent deformation caused by traffic.</td>
<td>Extends the life of pavements by protecting them against ageing and the environment, but do not contribute to the structural strength of the pavement.</td>
</tr>
<tr>
<td>Closed Joint systems</td>
<td>Be placed between two pavements to accommodate movements, improving waterproofing, ride quality, noise reduction.</td>
<td>Can accommodate various movements.</td>
</tr>
<tr>
<td>Joint materials</td>
<td>Be placed between two pavements to accommodate movements, improving waterproofing, ride quality, noise reduction.</td>
<td>Can accommodate various movements.</td>
</tr>
<tr>
<td>Geometry design</td>
<td>To optimize gap plate width, thickness, edge geometry and the interface geometry.</td>
<td>Not applicable and can help determine the interface stress or the internal stresses within the joint materials.</td>
</tr>
<tr>
<td>Stress absorbing membrane</td>
<td>Absorbs movements at the joints and reduces the stress it reaches the overlay.</td>
<td>Relieve the stress and usually varies from 0.6-1.0 cm.</td>
</tr>
<tr>
<td>Interlayer systems</td>
<td>Compress the grout, and to composite to reinforce the HMA overlay, and propagated in (a) low cost to absorb excessive stress.</td>
<td>Most used, and the performance highly depends on proper construction procedures.</td>
</tr>
<tr>
<td>Reinforcement interlayer</td>
<td>To reinforce overlaps in the event of excessive yielding or fracture of interlayer.</td>
<td>Initial high cost of construction but can extend lifespan.</td>
</tr>
</tbody>
</table>

3. What contributions from the road infrastructural perspective

The success of the E-Road infrastructure not only relies on the technologies allowing for charging action, but also their appropriate integration into the road structure and the good functionality in the long service lifetime.

1. The fragile materials, e.g. ferrite, have to be integrated into the road pavement to give a long service life in a very hostile environment.
2. The protection of the road structure is also essential. If the E-Road is damaged during their designed service lifetime, it can also affect the IPT system’s sustainability and functionality, leaving the whole system in a malfunction situation.
3. In order to ensure the optimum functionality of E-Road for a very long time and in a cost-effective way, the traditional maintenance technologies and management can be challenged.

Summary of the findings

From the road infrastructure perspective, this paper tried to survey the potential challenges that have not been taken into account for the success of E-Road infrastructure. The conclusions are given as follows:

- Different charging solutions are being under investigation as options for the future EVs’ charging infrastructure. In this, the Inductive Power Transfer technology has shown good characteristics and studied actively as used in the contactless charging solution.
- From the road infrastructure point of view, there is a large challenge over the success of E-Road structure in its long service lifetime.
- Overlay, joint and interlayer systems can enhance the structural integrity of composite road surfaces. However, their real effectiveness in E-Road is unknown and needs further investigations.
- Long-term maintenance management for E-Road is important but also challenged potentially.

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**FIGURE 2 Schematic of different transmitter’s configurations in IPT off-road systems**

**FIGURE 3 Illustration of cross section geometry of roadway and pickup inductor (after PATH, 1994)**

**FIGURE 4 Schematic of reflective cracking mechanisms due to (a) traffic loading and (b) temperature variations (after Lyttton and Mukiht, et al.)**