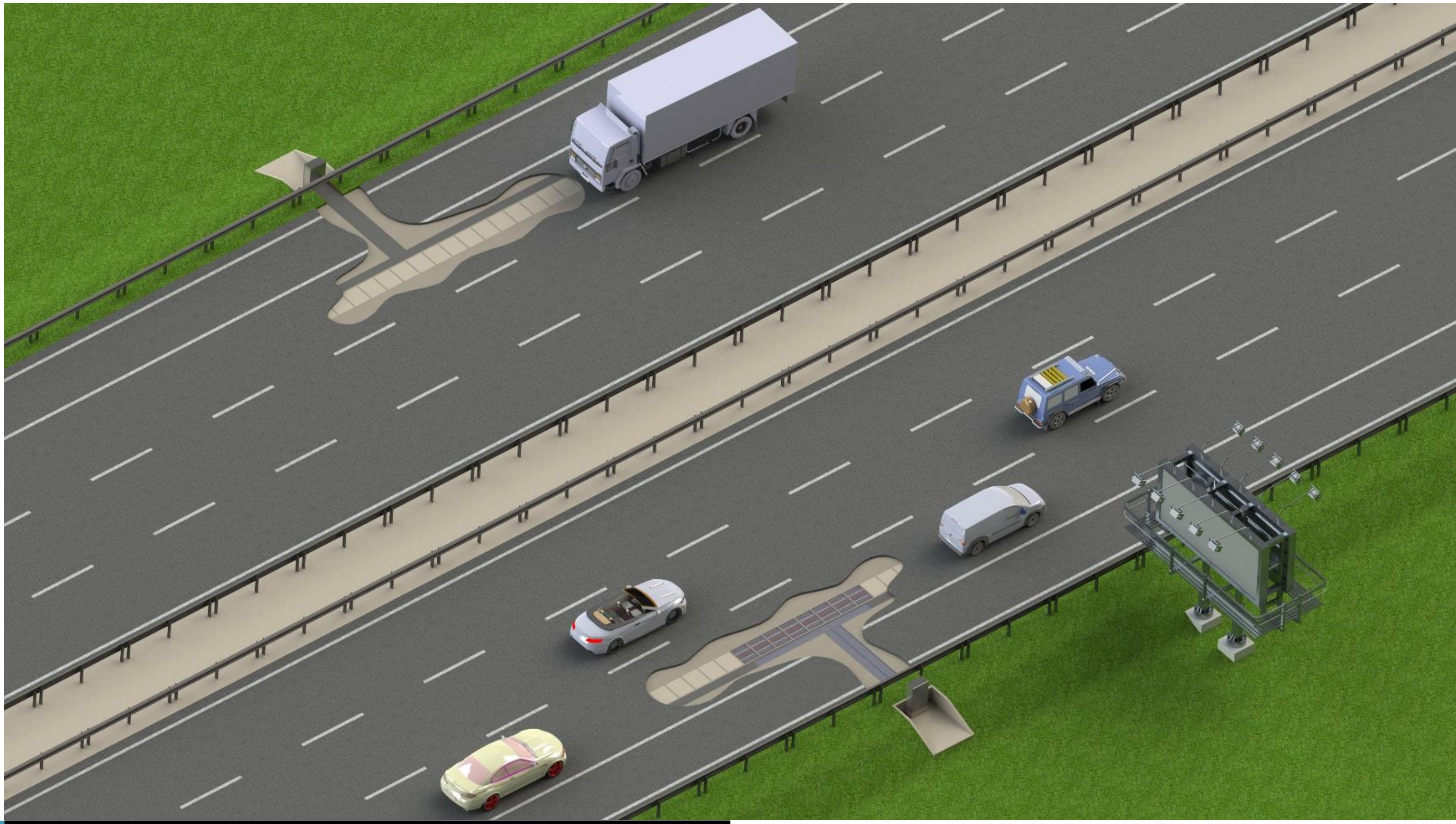


WHY YOU NEED MAGNETIC CONSTRUCTION MATERIALS FOR WIRELESS POWER TRANSFER

MAGMENT

August
2023

WHITE PAPER

1. INTRODUCTION

The white paper “WHY YOU NEED MAGNETIC MATERIALS FOR WPT” explains the main benefits of using magnetic materials in Wireless Power Transfer (WPT) systems. This paper explains why a magnetizable material based on cement or asphalt is highly superior in both cost and transmission efficiency compared to traditional ferrites. This paper presents a simulation scenario comparing two 50 kW WPT systems, one having a core made from ferrite tiles and the other a core made of magnetizable concrete.

2. PROBLEM DEFINITION

A WPT system, in its basic form, consists of two coils placed at a certain distance from each other. The coils are magnetically coupled, so that when one coil is supplied with AC current, an AC voltage is induced in the other coil and vice versa. This magnetic coupling enables a wireless transfer of power from one coil (termed the transmitter or Tx coil) to the other coil (termed the receiver or Rx coil), by means of a time varying magnetic field. The receiver coil can be placed on a stationary or moving electric vehicle, while the transmitter coil can be placed on the floor or as part of the road infrastructure, enabling thereby wireless charging of the battery in an electric vehicle. The coil and electronics located in the vehicle is therefore commonly called the Vehicle Assembly (VA), while the coil installed in the ground is commonly called the Ground Assembly (GA).

3. ANALYSIS OF MAGNETIC CORE IMPACT ON WPT SYSTEM PERFORMANCE

The simulation was done with two systems designed to work at a power level of 50 kW and a frequency of 85 kHz, with an identical Receiver (Rx) pad but with different Transmitter (Tx) pads – one with a **2nd Gen percolating magnetizable concrete (MC120®)** core with a thickness of 50 mm and the other one with a ferrite-tile core (such as N95 from TDK) with a thickness of 10 mm. The width and length of the cores, as well as the winding dimensions, are the same for both systems. The variant with magnetizable concrete uses a copper tube with an outer diameter of 18 mm and wall thickness of 1 mm as the conductor, while the variant with ferrite core uses a Litz-wire conductor with 4500 strands of 0.1 mm in diameter. The overall system performance was analyzed for a coil-to-coil distance of 350 mm and a 100 mm lateral misalignment. Both ground assemblies were pre-cast in a concrete housing (C50/60) prior to installation under the road surface. The resulting effect of hydrostatic pressure on the magnetic properties result on a permeability drop [1,2] and core loss increase [3,4] was considered. The results of this comparison are shown in Table 1.

Table 1. Comparison of two 50 kW WPT systems with Magment MC120® and ferrite tiles core

	Symbol	MC120® core 50 mm thick	Ferrite tiles 10 mm thick	%-Difference vs. MC120®
Coil-To-Coil Distance (mm)	D_{cc}	350	350	**0 %**
Lateral misalignment (mm)	Δy	100	100	**0 %**
Output power (kW)	P_{out}	50	50	**0 %**
Input power (kW)	P_{in}	53	54	**-2%**
Transfer efficiency (%)	η	94	92	**+2 %**
Coupling factor	k	0.15	0.16	-7 %
Tx coil current (A_{RMS})	I_{AC1}	101	92	**+9%**
Tx coil voltage (kV_{RMS})	U_{AC1}	2	1.9	**+5%**
Tx core losses (kW)	P_{c1}	1.6	2.3	**-44 %**
Tx coil losses (W)	P_{w1}	523	126	**+76 %**
Tx coil temperature (°C)	θ_{w1}	86	99	**-15 %**
Tx core temperature (°C)	θ_{c1}	81	104	**-28 %**
Magnetic field at distance 1.5 m from the transmitter pad (µT)	B	15	14	**+7%**

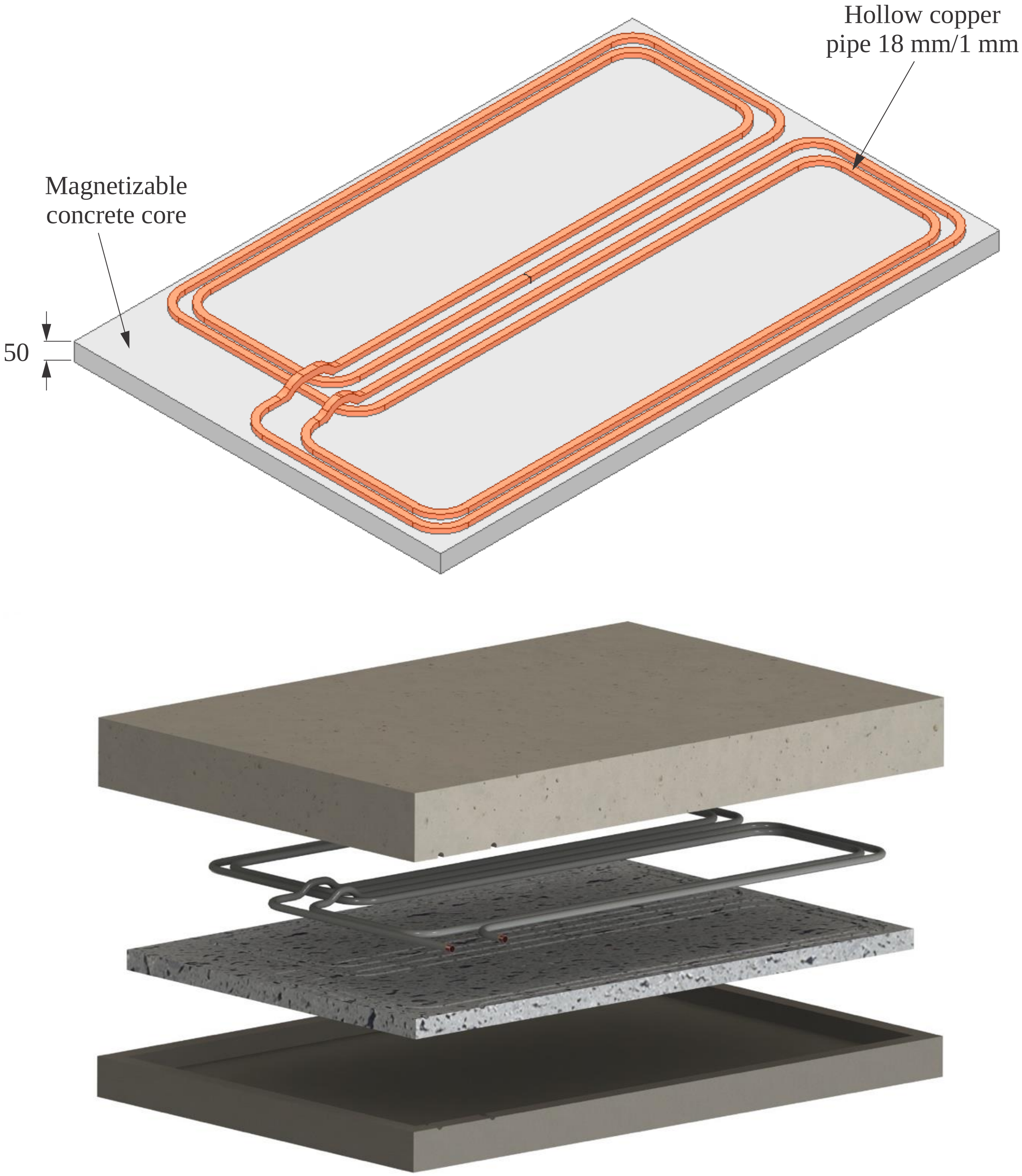


Fig. 1 Tx pad with magnetizable concrete core (Magment MC120®, 50 mm thick)

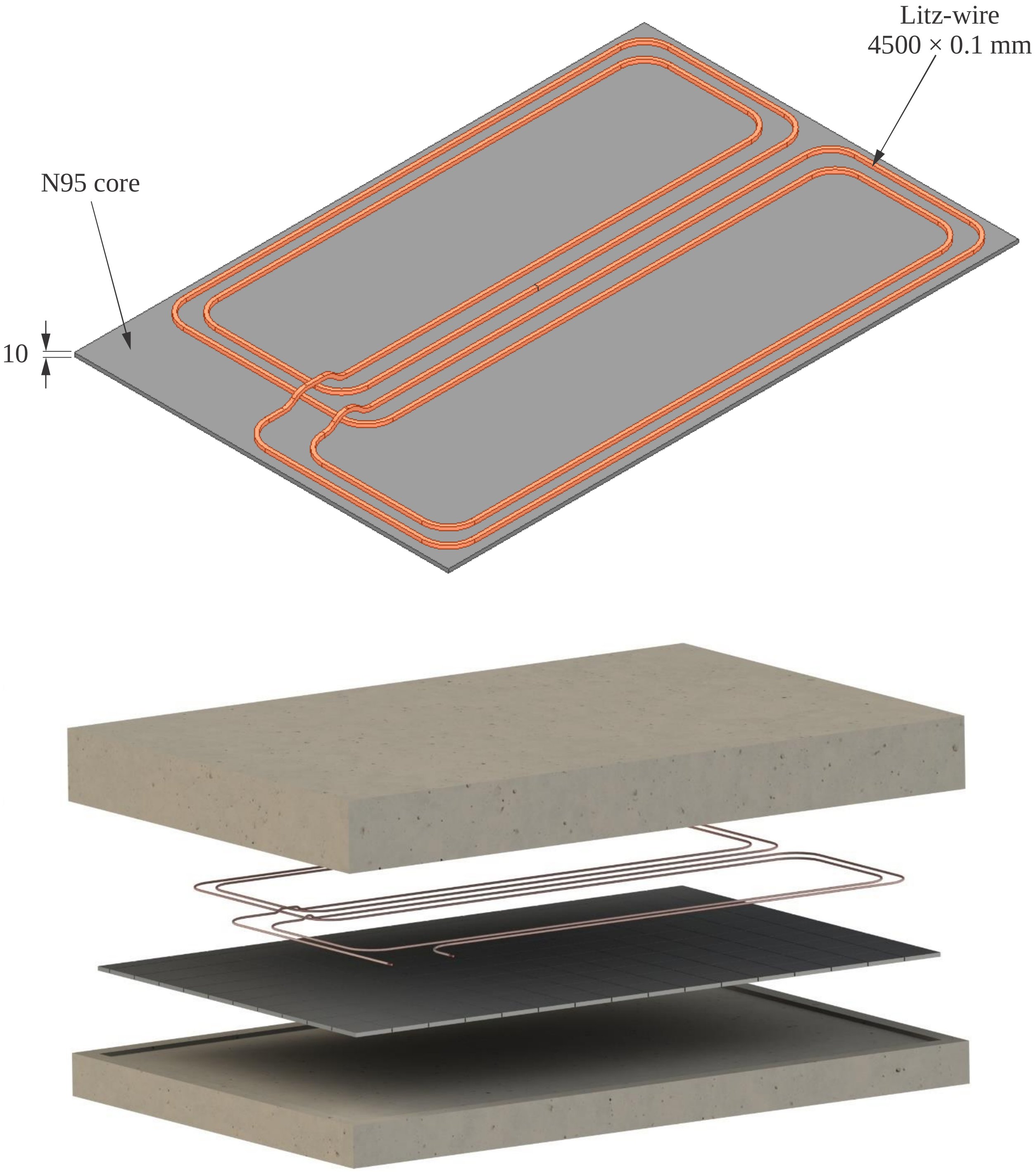


Fig. 2 Tx pad with ferrite core (N95, 10 mm thick) embedded in MC50/60 concrete

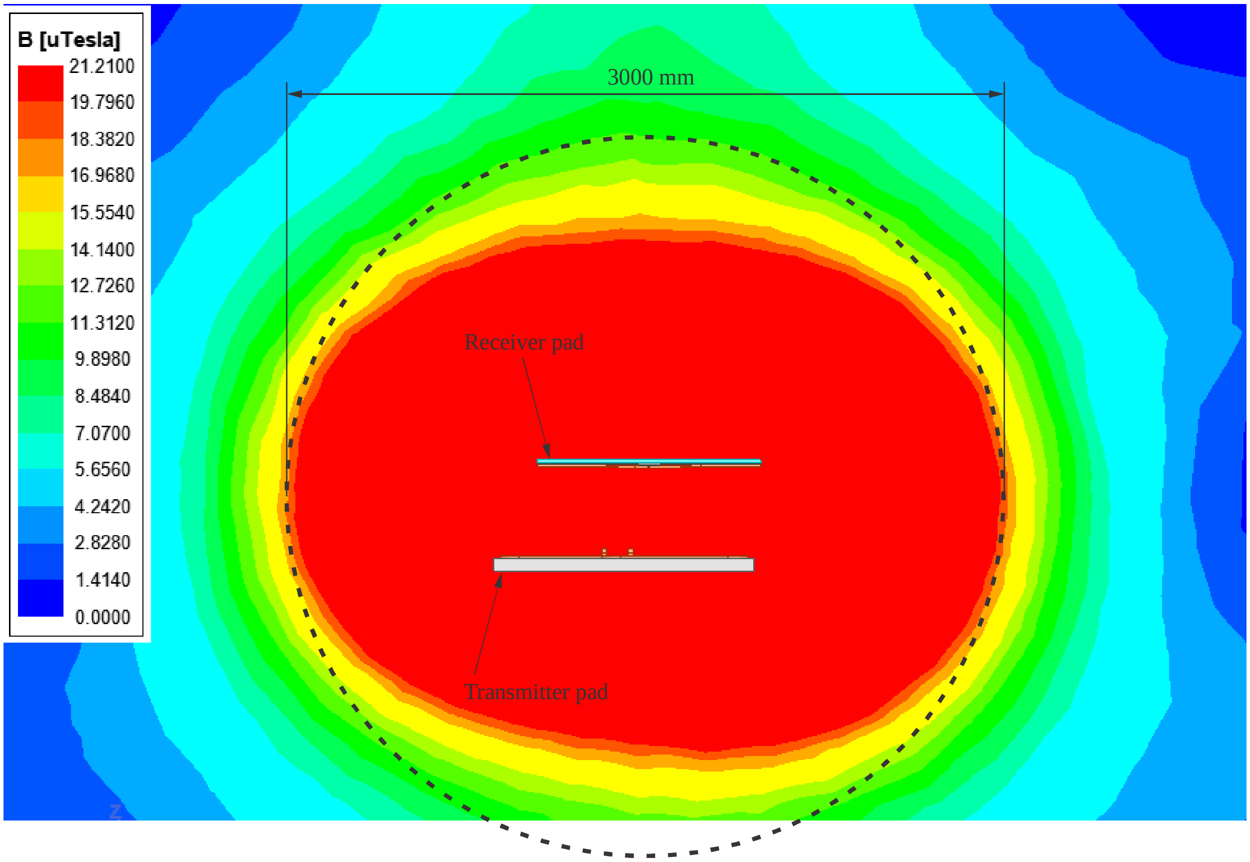


Fig. 3 Leakage field in the vicinity of Tx pad with magnetizable concrete core (Magment MC120®, 50 mm thick) for coil-to-coil distance 350 mm and lateral misalignment 100 mm (limit value of 15 µT$_{RMS}$ (21.21 µT$_{Peak}$) is achieved at distance 1500 mm from Tx pad center)

The Tx pad with the magnetizable concrete core (Magment MC120®) is shown in Fig. 1, while the Tx pad with the ferrite-tile core is shown in Fig. 2. The leakage field in the vicinity of both IPT systems are shown in Figs 3 and 4 for a coil-to-coil distance of 350 mm and lateral misalignment of 100 mm between the Tx and Rx pads.

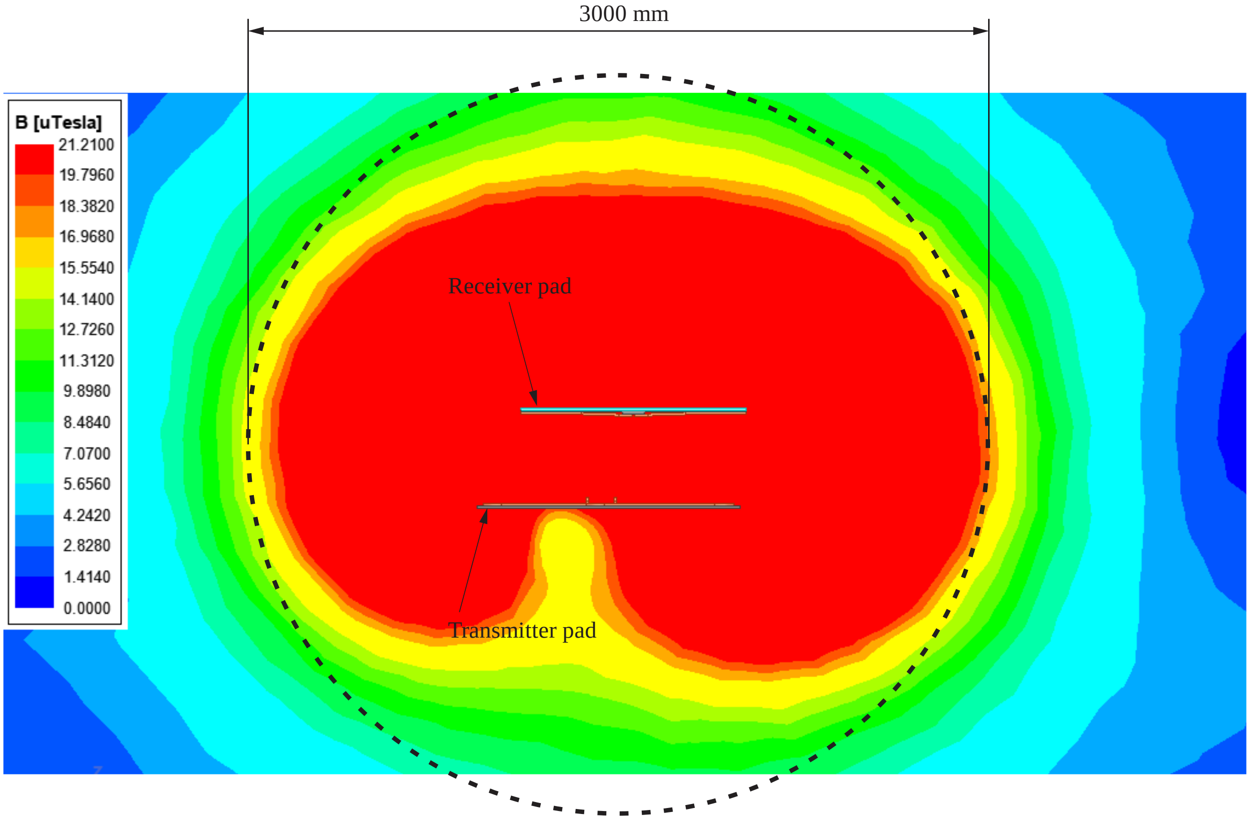


Fig. 4 Leakage field in the vicinity of Tx pad with ferrite core (N95, 10 mm thick) for coil-to-coil distance 350 mm and lateral misalignment 100 mm (limit value of 15 μT_{RMS} (21.21 μT_{Peak}) is achieved at distance 1450 mm from Tx pad center)

4. STRUCTURAL AND COST ANALYSIS

For magnetic concrete pavements, the maximum size of the coarse aggregate to attain the required magnetic properties must be small enough to remain suspended within the fresh concrete mix without breaking the surface or impeding the compaction of the concrete. This is essential to avoid slab deterioration securing long term stability of the road. For this reason international construction standards recommend that the thickness of the slab be at least three times the maximum nominal size of the aggregate material used.

When evaluating the correlation between cost and performance, the use of magnetic concrete has convincingly demonstrated a remarkable potential to outperform traditional Tx pads using ferrite-tiles cores. The equivalent conventional arrays used demonstrate that while delivering comparable results in power transfer ability, the ferrite-tile based system has a significantly higher cost. Specifically, the costed bill of materials (BOM) for the traditional array is 2.5x – 3.5x more expensive than that of the magnetizable concrete solution. Moreover, when considering the complete assembling cost of the ferrite core transmitter against its magnetizable concrete counterpart, the former is notably pricier, with a cost differential of 3x to 4x.

It's essential to note that this cost comparison is grounded on both systems achieving a power transfer efficiency level surpassing 92%. An alternative perspective emerges when investigating a scenario in which the thickness of the ferrite core is reduced to make it cheaper while maintaining a power transfer efficiency of minimum 90%. Under these conditions, the analysis yields a cost comparison of 2x - 3x in terms of the BOM and a 2.5x – 3.5x difference considering the completely manufactured Tx coil. It's worth highlighting that, even with this optimization, the ferrite-based coil remains costlier than its magnetizable concrete-based counterpart.

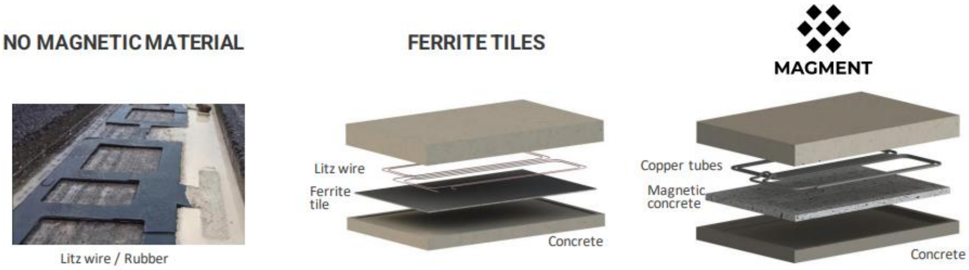
The use of magnetizable concrete therefore presents a compelling case not only for superior performance but also for a substantial reduction in cost compared to the traditional ferrite-tile core based counterparts. This analysis underscores the economic viability of embracing magnetizable concrete technology in pursuit of enhanced efficiency and cost-effectiveness for power transfer systems and the ability of maintaining a cost-efficient manufacturing process of WPT systems in the future.

5. CONCLUSIONS

This paper presents a paradigm shift for the design and deployment of efficient Wireless power Transfer (WPT) through a meticulous exploration of magnetic materials. The utilization of magnetizable concrete, a composite material produced with either cement or asphalt, has emerged as a transformative advancement that goes beyond a mere incremental progress. In contrast to traditional ferrite-based counterparts, magnetizable concrete offers a range of nuanced and substantial improvements, solidifying its place at the forefront of WPT innovation (Fig. 5).

The analysis conducted in this paper shows that the use of a magnetizable concrete core as part of GA in a WPT system can bring following benefits compared to ferrite-tile cores:

- Significantly reduce the losses in the GA coil for the same power, coil-to-coil distance, and GA coil geometry by almost 45 %.
- The study underscores the economic feasibility of substituting traditional ferrite-tile cores for magnetizable concrete, given its capacity to outperform the former while being cost-effective and drastically reducing total costs for the GA.
- The scalability and local manufacturing of WPT projects using magnetizable concrete stands out as a significant advantage of the magnetizable concrete GA, underscoring its economic feasibility and practicality. The study's findings of magnetizable concrete improving on traditional ferrite cores in both performance and cost-effectiveness, strongly support its potential for scalability. This adaptability extends its benefits to various applications and scales, ensuring the advantages seen in the study are not limited but can be applied to larger and more complex projects. Magnetizable concrete's consistent delivery of enhanced efficiency and cost reduction as projects expand solidifies its position as an innovative force set to transform wireless power transfer systems. Magnetizable concrete as well lends itself to the use of traditional civil engineering construction and manufacturing techniques, generating savings in installation and allowing for scalability.
- An important benefit of magnetizable concrete over traditional ferrite-tiles is the important reduction of around 28% in coil temperature, significantly reducing the hazards associated with high temperatures. This difference not only enhances safety by minimizing overheating risks but also showcases the technology's practicality and reliability. Reduced coil temperature reaffirms its suitability for applications prioritizing safety and robust performance.
- This white paper highlights the immense potential of magnetizable concrete in revolutionizing WPT systems. Beyond its evident technical superiority, the material's cost-effectiveness positions it as a formidable contender in the evolution of power transfer technologies. The findings of this study not only highlight the viability of magnetizable concrete-based solutions but also pave the way for a more efficient and cost-conscious future of WPT systems.



	NO MAGNETIC MATERIAL	FERRITE TILES	MAGMENT
Materials cost	🟡	🟡	🟢
Installation costs	🔴	🟡	🟢
Road construction regulations	🔴	🔴	🟢
Local sourcing	🔴	🔴	🟢
Standard construction method	🔴	🔴	🟢
Radiation emissions regulations	🔴	🟡	🟢
Efficiency >90%	🔴	🟢	🟢

Fig. 5 Tx technology benchmark for competing solutions vs. magnetic construction materials

LITERATURE

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