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Experimental Investigation on Magnetic Concrete for Wireless Charging

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Abstract: *This paper proposes methods of predicting and preventing thermal failure within high-power ferrite structures of electric vehicle (EV) wireless charging inductive power transfer (IPT) by improving their ferrite layouts. A high-power IPT magnetic design suitable for wirelessly charging an EV at 50 kW using a heuristic approach is presented where the chosen design achieves reduced heating within the magnetic structure. Recommendations are made that both avoid ferrite fracturing due to magnetic hotspots and cause temperature differentials across ferrite tiles, and regarding airgap distribution between ferrite tiles to reduce loss-inducing circulating flux within the ferrite structure without reducing coupling*

Wireless charging is an attractive option of energy replenishment for electric vehicles (EVs) as it does not require direct electrical contact to the EVs. However, the radiated magnetic field from the EV wireless charging system can be an electromagnetic compatibility (EMC) concern nearby electrical and electronic devices. This paper investigates the influence of the power level, the clearance, and offset between coils on the radiated magnetic field emitted from the wireless charging system. The experimental study shows that these variable parameters can affect the radiated magnetic field level and the field distribution, which provides valuable input for standardization of the test setup and working condition of the EV wireless charging system.

Keywords: electric vehicle

I. INTRODUCTION

The production of magnetic concrete involves integrating soft magnetic components, such as crushed ferrite, iron oxide grains, or scraps of amorphous or nano-crystalline metallic magnetic materials, into a typical cement slurry. This process results in the production of magnetic concrete. This leads to the production of magnetic concrete as a result (cement and water mixed together). In common parlance, this particular mixture is referred to as "magnetic cement mortar,"which is also one of its common names. A certain sort of concrete that exhibits certain magneticproperties can be obtained by first vibrating the mixture, then compacting it, and then allowing it to cure for the desired amount of time.

E-mobility encompasses all forms of automobile transportation, including private auto mobiles, commercial trucks, and most notably buses, and it has the potential to significantly cut down on air pollution in large urban areas. Electric vehicles are the ideal answer to lessen the impact that internal combustion engine vehicles (ICEVs) have on the environment because fuel resources are running out and there is concern for the environment. Charging stations that are able to assure the charging of their batteries at home, in parking lots, while they are on the route, or at depots are required for all of them. The conventional way of conductive charging has several disadvantages, but the novel approach of wireless charging has many advantages.

Limitations of study

Power consumption:

According to the findings of the survey, the typical electronic vehicle has an energy consumption of about 0.2 kilowatt hours per kilo metre. This is a pretty high consumption when considering the amount of power that is necessary to recharge the vehicle.

Cost of vehicle:

In India, the adoption of electric vehicles is restricted because of high cost of purchasingsuch vehicles. The high initial cost of purchasing an electric automobile is now a significant barrier to entry for prospective buyers. Even while this can be countered by the low costs of fuel, running and maintenance as well as tax benefits, it is still a decidingissue for many people because for the same money, one can get a larger gasoline- powered vehicle.

Advanced technology:

A high level of technological sophistication is essential for the implementation of this technique.

II. LITERATURE SURVEY

A Comparative Assessment of Magnetic Concrete versus Ferrite for a High Power Inductive Coupler Andrej Marinescu-(2021)-Yuvraj S. Narayanmurthi R , jagbar Sathik Ali and Dhafer Almakhles.

This paper assesses the possibility of replacing the brittle ferrites used in classical constructionswith Magnetic Concrete. The air pollution in large urban agglomerations can be drastically reduced by electrical mobility which covers all means of road transport: personal cars, freight cars and especially buses. All of them are dependent on the existence of charging stations that are able to ensure the charging of their batteries at home, in parking lots, on the route or in depots. Compared to the classic, conductive charging, contactless charging (Wireless Power Transfer - WPT) is a disruptive technique with numerous advantages that allows static, semi- dynamic (opportunity charging) and dynamic charging of batteries.

Challenges in the Electromagnetic Modeling of Road Embedded Wireless Power Transfer. - Vincenzo Cirimele, Riccardo Torchio, Antonio Virgillito, Fabio Freschi, PiergiorgioAlotto. (2019).

In this paper, starting from the experimental experience of the road embedment of a transmittingcoil for wireless power transfer, a numerical model of such device is constructed. The model isthen used to perform several parametric analyses which aim at investigating the influence of the main electromagnetic parameters of the concrete and the geometrical parameters of the wireless power transfer on the overall behavior of the device. The results of such study allow for providing guidelines for the design of the coil and the choice of the materials for the embedment. Moreoveras a secondary result of the adopted methodology, the electromagnetic characterization of the concrete adopted for the road embedment is obtained. In this work, the influence of the electromagnetic parameters of the concrete on the direct road embedment of atransmitting coil for a WPT system for electric vehicles has been investigated. Such the study has been motivated by the issues which emerged during the experimental experience of the direct road embedment of a coil. The main results of this work consist of: • the electromagnetic characterization of the concrete involved in the road embedment (at 28 days after pouring), • the study of the influence of the turns spacing, the insulator thickness, and the concrete resistivity and relative permittivity on the overall electromagnetic behavior of the embedded coil.

Inductive Power Transfer for Charging the Electric Vehicle Batteries -Mohammed Al-Saadi, Ammar Ghalib Al-Gizi, Ali Hussein Al-Omari (2018)

The stationary and dynamic charging methodologies have discussed briefly in this research. Wireless power transfer (WPT) technologies have been developing rapidly in recent years. Advances in technology make WPT widely used in many applications. Electric vehicle (EV) contactless charging is an important application of WPT. Broadly, WPT categorized into radiative and non-radiative power transfer. Radiative power transfer is transmitting high power density, which is unsafe for humans when it is been used for EVs charging. So, only non-radiative power transfer technologies have been using to charge the batteries. Non-radiative power transfer includes inductive power transfer (IPT) and capacitive power transfer (CPT).

Power efficiency improvement of wireless power transfer using magnetic material .-Shigefumi Morita, Takuya Hirata, Eko Setiawan, Ichijo.(2017)

In this paper Efficiency improvement of wireless power transfer system is studied using ferrite bars with keeping distance of electric power transmission is studied. Experiments are performed to decide better installation of ferrite bars for improving efficiency; there are many possibilities how and where to install them. We conducted several experiments and devised a method of installing ferrite bar with high effect on WPT. Each result is compared with the case of no ferrite bar system. The result of experiments shows using ferrite bars is practical and cost effective. Some suggestion is given to drive wireless power transfer system with lower frequency, which is also noteworthy about the limitation of available power source. In this paper proposed the method of adding ferrite bars to improve the efficiency and power of WPT system. We have tried several numbers of bars and the cases when adding bars either transmitting coils or receiving coils, or the both, and shown experimental results which describe the effect of bars. Although the effect cannot be regarded drastic, it offers extra choices of driving frequency without losing efficiency and power. Putting a relay coil between transmitting and receiving coils is a popular method to improve WPT system but it does not keep the space between the transmitter and receiver open. Our method does not affect the space and improve the efficiency of system.

III. METHODOLOGY

Data Collection:

We went to a number of websites in search of information related to our topic, located a few research papers, read through them, and then had a discussion about the topic with our instructor.

3.1 Neodymium Magnet:

A neodymium magnet (also known as NdFeB, NIB or Neo magnet) is a permanent magnet made from an alloy of neodymium, iron, and boron to form the $Nd_2Fe_{14}B$ tetragonal crystalline structure. They are the most widely used type of rare-earth magnet. Developed independently in 1984 by General Motors and Sumitomo Special Metals, neodymium magnets are the strongest type of permanent magnet available commercially. They have replaced othertypes of magnets in many applications in modern products that require strong permanent magnets, suchas electric motors in cordless tools, hard disk drives and magnetic fasteners.

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3.2 Test on material:

Compression strength test :

A compression strength test measures how much compressive force a material can withstand before breaking. It's a fundamental mechanical test that's used to determine a material's properties and behavior under crushing loads. Here's how a compression strength test is performed:

- A test specimen, usually in the shape of a cylinder, prism, or cube, is placed in a compression-testing machine.
- A gradually increasing compressive load is applied to the specimen.
- The maximum load the specimen can withstand before breaking is recorded.
- The appearance of the specimen and any unusual features of the break are noted.
- The test results are plotted on a stress-strain diagram, which can be used to determine the material's elastic limit, yield point, yield strength, and other properties.
- Compression tests are important for determining if a material is suitable for a specific application or if it will fail under certain stresses

Durability Test:

A durability test, also known as reliability testing or endurance testing, is a systematic process that assesses a product's performance, strength, and lifespan under various conditions. The test simulates the wear and tear that a product experiences during its intended lifespan in a shorter time frame.

Durability tests can help manufacturers produce more durable products by providing data on how a product will perform over time. For example, tests can recreate real-world conditions to determine how a product will be affected by temperature, humidity, UV exposure, and weathering.

Here are some examples of durability tests:

- **Life cycle testing:** Also known as accelerated life cycle testing, this method simulates a product's life in a shortened time frame.
- **Simulation tests:** These tests reproduce a recorded load-time signal on a test bench.
- **Door slam test:** This test is used to determine how well a door can withstand being slammed.

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3.3 Process of manufacturing Concrete roads:

The production of cement concrete pavement tiles involves a number of steps, including administration, mixing, compression, and drying at the end of the process. For cement concrete paving stones with a water-cement ratio of 0.62, a concrete mixture with a volume of 1:3:6 (cement sand: aggregate) can be used. This ratio is for the cement: sand: aggregate component of the mixture. The concrete mixture should not be any thicker than 1:6 with respect to the combined aggregate before it is mixed. This ratio is determined based on the volume of cement. The combined aggregate fineness module ought to be between 3.6 and 4.0. Put all of the materials into a concrete mixer, and let the mixer turn for about 15 minutes. Take the created mixture out of the mixer and be sure to eat it within the following half an hour. It is possible to compress the concrete mixture into the necessary size and shape by making use of a vibrating table. After the tiles have been compressed, take them from the mould and shield them for the next 24 hours from direct sunlight and wind. This process is used to cure the tiles. Following the curing process, the tiles are allowed to naturally dry before being distributed for use. Paving stones made of concrete gain a significant amount of strength within the first three days of the hardening process, and this increase is assured to reach its full value within the first ten to fifteen days. After the curing process, the tiles are allowed to cure in the shade until the initial shrinking is complete. Only then may the tiles be used for work. In most cases, the drying and shrinking process takes between 7 and 15 days to finish, after which it can be used. Concrete tiles are produced in a manner analogous to that of bricks by pressing the mixture in a semi-dry state before allowing it to cure for 24–36 hours. permits it to age in the tank for a period of 15 days. If it is desirable, water can be sprayed so that maximum fitness can be achieved in 15–21 days.

Method 1: Electromagnetic Induction (EMI) Roadway

- Installation of electromagnetic coils: Place coils beneath the road surface, spaced at regular intervals.
- Magnetic field generation: Electric current flows through coils, generating a magnetic field.
- Wireless charging: Vehicles equipped with compatible receivers can charge while driving.

- Power transmission: Electricity transmitted through coils to vehicles.

Method 2: Magnetizable Concrete Roadway

- Specialized concrete: Mix magnetizable materials (e.g., ferromagnetic powders) into concrete.
- Road construction: Lay magnetizable concrete slabs, forming the road surface.
- Magnetic field creation: Embed permanent magnets or electromagnets beneath the surface.
- Wireless charging: Vehicles with compatible technology can harness energy from magnetic fields

Steps for execution for construction of roads:

Batching:

The process of batching concrete involves measuring the components or ingredients needed to make the concrete mix, such as cement, sand, aggregate, and water, to ensure proper mixing in accordance with the mix ratio. To create high-quality concrete, each ingredient should be utilized in the proper amount. Batching is the process of measuring concrete mix ingredients either by volume or by mass and introducing them into the mixture

Mixing:

Mixing concrete is defined as the complete blending of the materials that are required for the production of homogeneous concrete. After batching, the material is then properly mixed to ensure a consistent color and the absence of any streaks.

Placing of material in the mould:

The next stage is to distribute the material throughout the mould in an even manner using shovels to properly pack the material into all of the corners of the mould.

Compacting of the material:

A surface vibrator is utilized for the purpose of compacting the concrete. The concrete mixture can be compacted using a vibrating table in the moulds of the specified sizes and shapes.

Curing and finishing of roads:

Curing is the process of maintaining a satisfactory moisturecontent and a favorable temperature in the time immediately following placement. The Concrete tiles are similarly produced with the help of semi-dry pressing of the mixture and allowed to set for 24–36 hours. Water curing is not performed for these tiles as the tiles are leftto dry in the shed after demolish to achieve the desired strength.

Execution And Construction:

Trial no 1: For ferrite Powder

Step No:1 Batching of Materials:

- Ferrite
- Cement
- Crush sand
- Aggregate 10mm
- Concrete additive
- Water

Step No 2: Mixing of Materials:

After batching the material is then properly mixed to ensure a consistent color and the absence of any streaks. The Hand Mixing procedures have to be carried out only for small concrete works.

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Step No 3: Placing of material in the mould:

The next stage is to distribute the material throughout the mold in an even mannerusing shovels to properly pack the material into all of the corners of the mold.

Step No 4: Compacting the material:

A surface vibrator is utilized for the purpose of compacting the concrete.

Step No 5: Curing and finishing of roads:

Curing is usually done by sprinkling water on the tile joints to ensure sufficient strength and bonding of cement mortar. Tile Wash. To maintain tile's original finish at the end of this exercise, tile wash is recommended.

sheens but would rather keep your finishes separate, using gloss and matte finishes in the same room on different surfaces is a great way to achieve this look. Once the tiles have been compacted, remove them from the mould and protect them from wind and sunlight for the following 24 hours. The tiles are cured using this procedure. The tiles are thengiven time to naturally dry after the curing process before being used.

Step No 6: De-moulding of tiles after 24 hrs:

The shortest time after laying tile that you can grout is 24 hours. However, it is much better to wait at least 48 hours before grouting. This is to give the mortar ample time to set and dry before pressure is applied. But once the job is finished, there is a curing process to follow. The curation generally occurs in about twenty minutes; however, the tiles should not be walked on for a solid 24-hour time frame to allow them to set fully. It is a crucial period that will ensure the beauty and endurance of the materials.

3.4 Tests on Material:

Test on cement:

Fineness Test on Cement:(IS code 269)

The Fineness modulus of cement is determined empirically by adding the total percentage of an aggregate sample retained on each sieve in a specified series and dividing by 100.

Sr. No.	Description	1	2
1.	Weight of cement	100 gm	100 gm
2.	Weight of cement retained on 90 micron IS sieve	8.8	6.7
3.	Wight of cement passed through 90 micron IS sieve.	91.3	93.3
4.	Percentage weight retained on the sieve	8.8 %	6.7%
5.	Average	7.75%	

Results:

According to IS code 269, the weight of cement remaining on the sieving shall not exceed 10% of the total weight. The percentage of the cement sample retained on the sieve is 7.75 on average. Thus, the obtained cement fineness is within the acceptable range.

Following are the steps for determining the material quantities:

Create a spreadsheet in Excel that will allow you to determine the quantities by combining multiple formulas.

Select the required concrete grade initially.

Add the tile dimensions to the Excel sheet.

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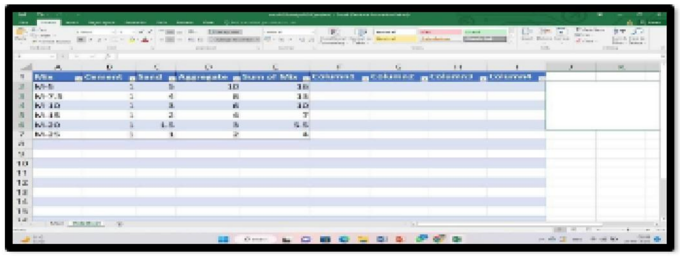
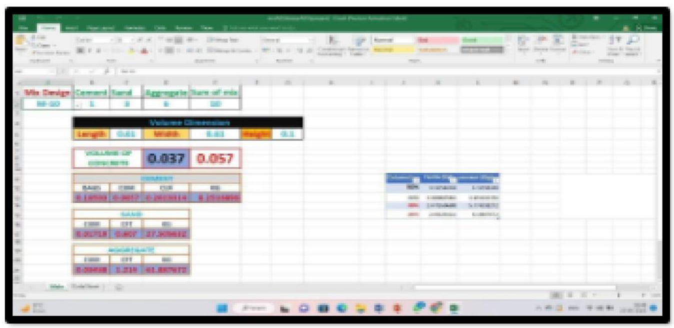
Then the volume of concrete is calculated in the Excel sheet.
After the calculation of the volume, the quantities of materials are formulated.





Execution And Construction:
Trial no 1: For ferrite Powder
Step No:1 Batching of Materials:

- Ferrite - 252gm
- Cement- 252gm
- Crush sand- 1683gm
- Aggregate 10mm-3788gm
- Concrete additive-5ml
- Water - 700ml

Step No 2: Mixing of Materials
After batching the material is then properly mixed to ensure a consistent color and the absence of any streaks. The Hand Mixing procedures have to be carried out only for small concrete works.

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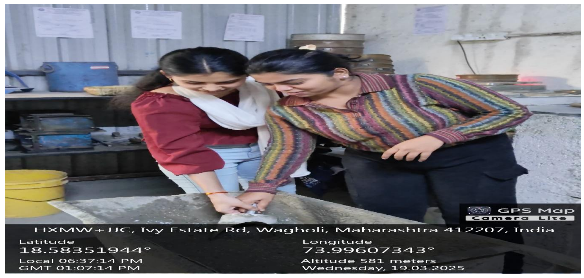

Step No 3: Placing of material in the mould.

The next stage is to distribute the material throughout the mold in an even manner using shovels to properly pack the material into all of the corners of the mold.

Step No 4: Compacting the material

A surface vibrator is utilized for the purpose of compacting the concrete.

Step No 5: Curing and finishing of cubes

Once the tiles have been compacted, remove them from the mould and protect them from wind and sunlight for the following 24 hours. The tiles are cured using this procedure. The tiles are then given time to naturally dry after the curing process before being used.

3.5 Compression testing:

The axial load carrying capacity of paving blocks is measured in accordance with BS 6717:1986 and SNI 03 - 0691 - 1989. The paving stones are placed in the compression device and the stress at failure is determined using the following formula:

$p\ \sigma = A$

Where: σ = the ultimate stress at failure in Mpa or kg/cm2.

P = the ultimate load at failure in Newton or kilograms.

A = the area perpendicular to the applied load, in mm2 or cm.

Procedure:

Preparation and Positioning of Specimens:

All testing machine bearing surfaces must be wiped clean, and any loose grit or other extraneous material must be removed from the specimen surfaces that will come into contact with the platens.

Loading:

The load must be applied without shock and gradually raised at a steady rate of 14 N/mm2/min until no more load can be maintained. The indicated maximum load must be noted.

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V. CONCLUSION

The development of magnetic concrete for wireless charging presents a groundbreaking opportunity to revolutionize the way we power our devices. By integrating magnetic materials into concrete, we can create a seamless, efficient, and safe charging experience. Magnetic concrete wireless charging represents a significant advancement in energy transfer technology, integrating the durability of concrete with innovative wireless charging capabilities. This approach enhances the convenience of charging electric vehicles, devices, and other applications by eliminating the need for physical connectors. The potential for embedding charging infrastructure directly into urban environments could lead to more efficient energy use and improved accessibility. However, challenges such as cost, energy efficiency, and the development of compatible devices remain to be addressed. Overall, the concept holds promise for a more integrated and sustainable future in wireless energy solutions.

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