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SAMPLE LANDSCAPE STUDY – Self-Healing Concrete

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1. INTRODUCTION

1.1. Self-Healing Concrete (SHC)

Concrete is the most important building material for infrastructure but most concrete structures are prone to cracking as the amount of available non-hydrated cement is less in traditional concrete mixture.

Repairs can be particularly time consuming and expensive because it is often very difficult to gain access to the structure to make repairs, especially if they are underground or at a great height.

A self-healing concrete material is described as a material that is capable of repairing itself when it comes into contact with moisture and carbon dioxide in the air and produces lime (calcium carbonate) on outer surface of concrete hence prevents cracks.

SHC prevents water to percolate into reinforced steel concrete hence prevents reinforcement corrosion. Self-healing of cracks in concrete would contribute to a longer service life of concrete structures and would make the material not only more durable but also more sustainable.

The healing process of SHC is promoted by addition of agents known as healing agents who are able to promote the deposition of crystals inside the crack.

Self-healing in cementitious materials can be classified broadly into three categories namely intrinsic healing, capsule based healing and vascular healing, in accordance with approaches which originate from self-healing agents.

1.1.1 Intrinsic Self-Healing

Intrinsic self-healing agents also known as autogenous healing materials exhibit self-healing properties due to the concrete composition.

The exact mechanism of intrinsic healing is a matter of debate till date but two mechanisms are popular. (i) Non-hydrated cement particles receive water and become hydrated allowing them to crystalize and (ii) Swelling of the matrix and blocking of the crack due to debris present in the ingress water or loose concrete particles resulting from cracking may also result in autogenous healing.

While different opinions exist about the main mechanism causing autogenous healing, researchers agree that for each mechanism, the presence of water is essential.

For sources of information, please refer to **Appendix A**

1.1.2 Capsule Based Self-Healing

Capsule based self-healing occurs when capsules of healing agents that are embedded in the concrete rupture by damage and a self-healing mechanism is triggered through the release of self-healing agents that either reacts with air, or another reactant that is embedded in the concrete matrix or other capsules. Chemical compositions or bacteria can be incorporated in capsules and the benefit of bacteria is that certain bacteria can live for years without anything else inside the capsules while many chemicals lose their healing capabilities over time without a reaction.

Capsules can be made of polymers, glass, clay and other materials but polymer capsules have proved to be most efficient and successful throughout mixing and placing concrete. Capsules may have a spherical or cylindrical shape.

1.1.3 Vascular Based Self-Healing

Vascular based self-healing occurs when a healing agent is placed in a network of hollow tubes which run through the concrete from the interior to the exterior of the building. There can be one channel or multiple channel vascular healing systems depending on different factors such as number of healing agents, building shape, concrete strength, etc. The main problem with vascular based healing is that it is not as pervasive because the tubes must be placed in certain locations where cracks are anticipated to occur.

1.2. Growth Prospects of Self - Healing Concrete

The global self-healing concrete market size is expected to reach $US 1.3 Billion at 26.4% CAGR by 2025 attributing to the factors such as increased life of civil infrastructures and demand in building & construction and transportation industries. Also, rise in need for preserving the infrastructure, supplements the self-healing concrete market growth.

The market of Self-healing concrete has wide application base for reliable and durable construction in residential, commercial, industrial and civil infrastructure. Hence, saving maintenance cost and increasing the life of these structures will ensure ample opportunities for various self-healing product to enter the market.

It is a critical time to understand the global competitive environment of self-healing concrete technology from a patent perspective and in-depth patent analysis of key technologies and players can help anticipate changes, detect business opportunities, mitigate risks and make strategic decisions to strengthen one's

For sources of information, please refer to **Appendix A**

market position and maximize return on one's IP portfolio.

Some of the prominent participants in the global market of SHC include Basilisk, Acciona Infrastructures S.A., Avecom N.V., Comercializadora Espanola De Innovaciones Y Materiales, COWI A/S, Devan-Micropolis, and Fescon.

For sources of information, please refer to **Appendix A**

2. OBJECTIVES

- To perform detailed analysis of granted patents and published applications pertaining to Self-Healing Concrete and to understand underlying technologies.

- In depth analysis of patents/applications, in order to categorize them and to understand focusing areas of applicants.

- Graphical representation of trends (Filing, Publication, etc.) from the mined data of relevant patents/applications.

Image Courtesy

2.1 SEARCH METHODOLOGY

Image Courtesy

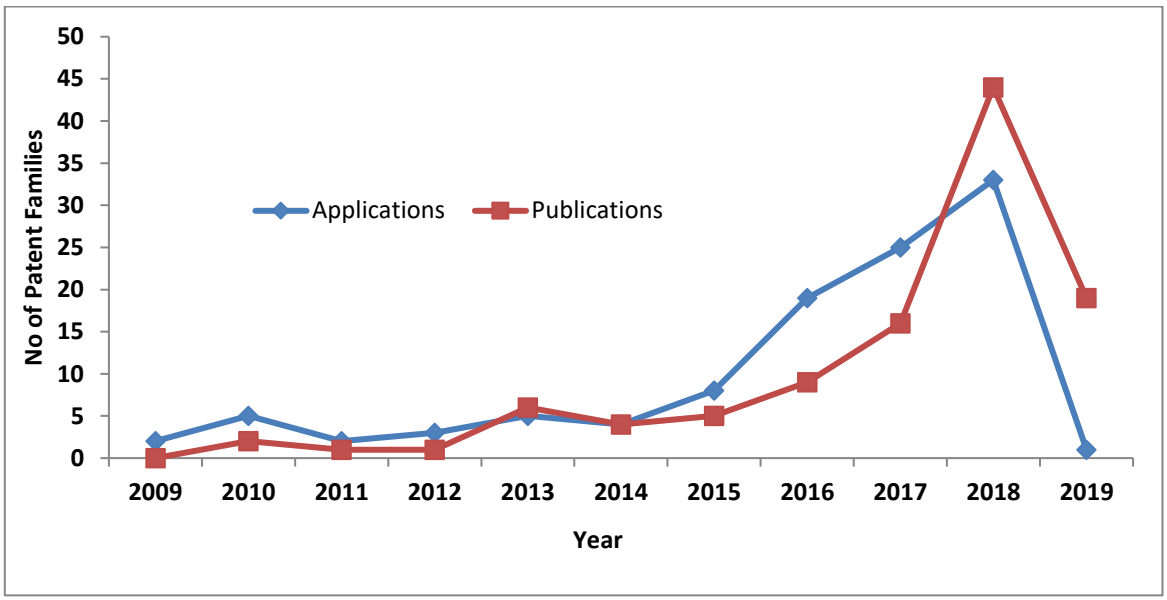
The first step is to create and define a patent set that will serve as the basis of analysis. Using renowned patent database, Derwent Innovation as our data source, we extracted data set of patents/published applications filed during the last ten years (2009-2019) by performing search in Abstract, Title, and Claims fields using keywords and International Patent Classifications.

3. TREND ANALSYS & GRAPHICAL REPRESENTATION

3.1 APPLICATION, PUBLICATION YEAR BASED TREND ANALYSIS

3.1.1 ANALYSIS BASED ON REPRESENTATIVE MEMBER PER INPADOC FAMILY

Below graph represents application year, and publication year trends for the patent publications pertaining to self healing concrete.



Note: Attributed to non-published patent applications, there may be a higher count in the years 2018- 2019.

INSIGHT:

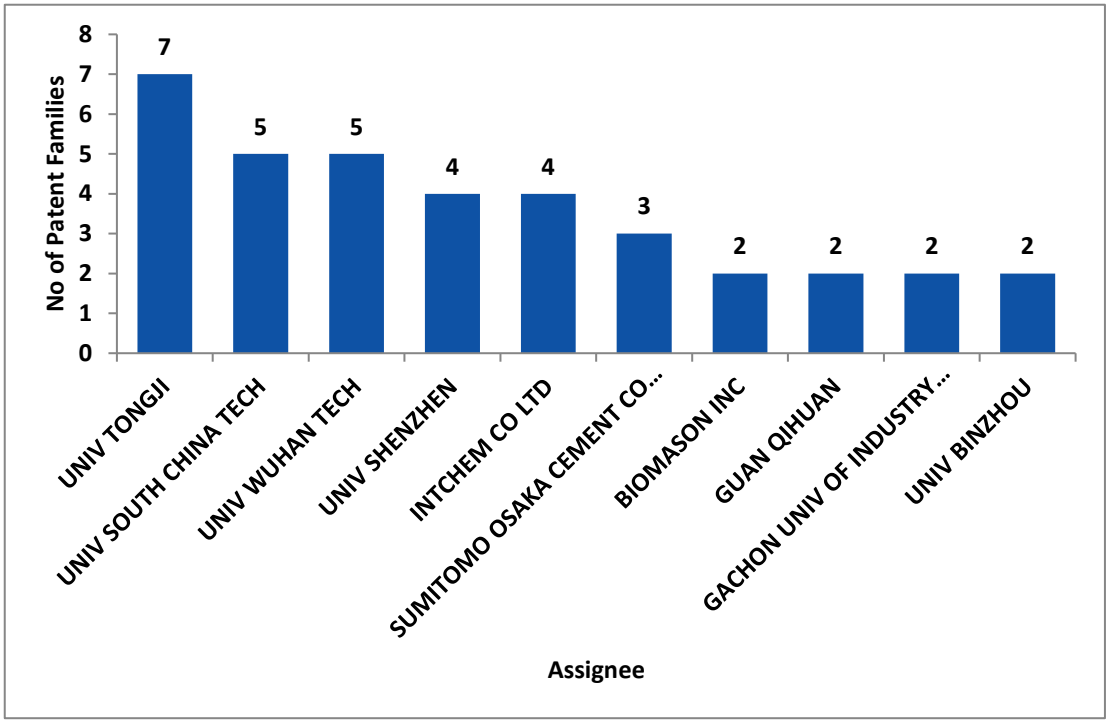
- Filing year trend provides insights for the number of applications filed during the period 2009-2019. As depicted in the graph, there is a gradual rise in patent applications filing over the years, wherein the maximum numbers of patent applications were filed in the year 2018.

- Publication trend provides insights for the number of applications published during the period 2009-2019. As indicated in the graph, there is a gradual rise in publication over the years, wherein the maximum numbers of patent applications were published in the year 2018.

3.2 ASSIGNEE BASED TREND ANALYSIS

3.2.1 MAJOR ASSIGNEES (BASED ON REPRESENTATIVE MEMBER PER FAMILY)

The below graph represents major assignees in the domain.

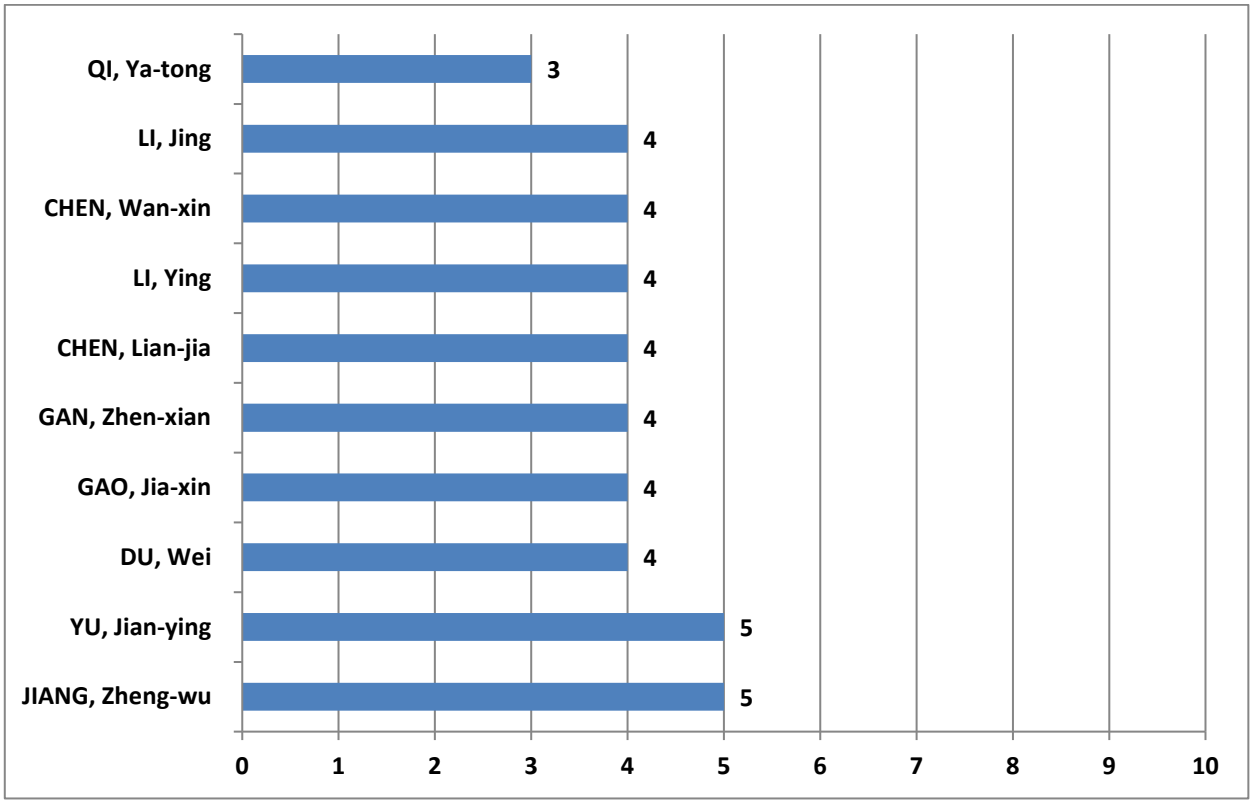


THE TOP ASSIGNEES ARE:

- TONGJI UNIVERSITY
- SOUTH CHINA UNIVERSITY OF TECHNOLOGY
- WUHAN UNIVERSITY OF TECHNOLOGY
- SHENZHEN UNIVERSITY
- INTCHEM CO LTD
- SUMITOMO OSAKA CEMENT CO LTD
- BIOMASON INC
- GUAN QIHUAN
- GACHON UNIV OF INDUSTRY ACADEMIC COOPERATION FOUNDATION
- BINZHOU UNIVERSITY

3.3 KEY INVENTORS

The below graph names the inventors with most number of innovations on their name.



INSIGHT:

The chart demonstrates top inventors, wherein **'Jiang, Zheng-Wu'** & **'Yu, Jian-Ying'** emerges out as the leading inventors in Self-Healing Concrete technology.

3.4 GEOGRAPHY BASED TREND ANALYSIS

3.4.1 GEOGRAPHICAL DISTRIBUTION OF PATENT APPLICATION FILINGS

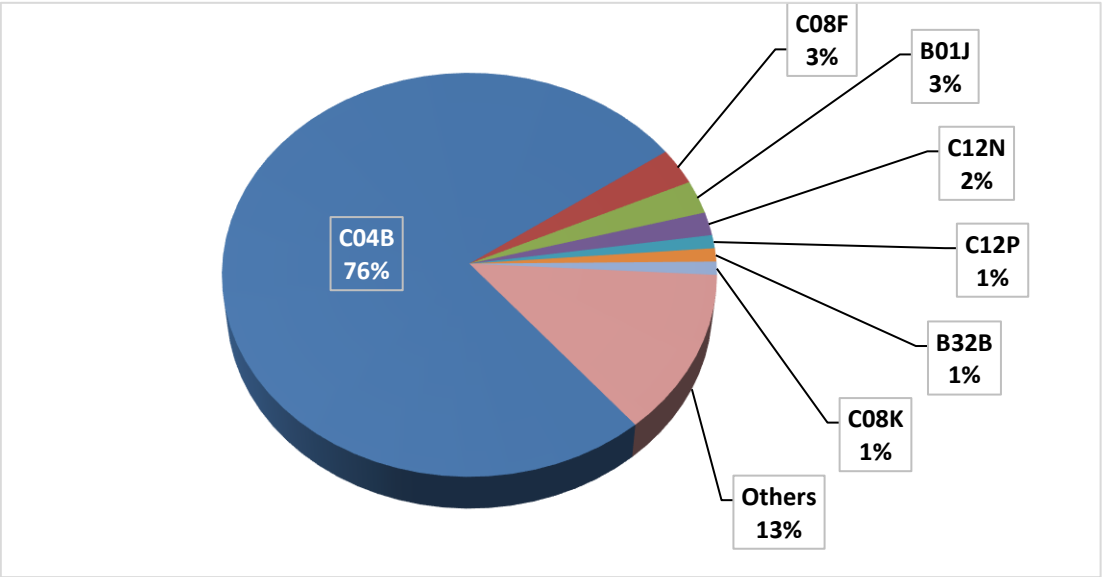
Priority Year → / Priority Country ↓	<2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Grand Total
CN	3	2		1	4	2	6	13	15	28	1	75
KR					2	1	3	2	7	2		17
US	2						1	2	2			7
JP	1		1	1			1	2				6
Others									1			1
Grand Total	6	2	1	2	6	3	11	17	25	30	1	106

INSIGHT:

Trend related to Geographical filing demonstrates that the maximum number of filings originated from CN followed by KR, US and JP jurisdictions.

3.5 INTERNATIONAL PATENT CLASSIFICATION BASED TREND

The below graph represents frequently assigned international patent classes.

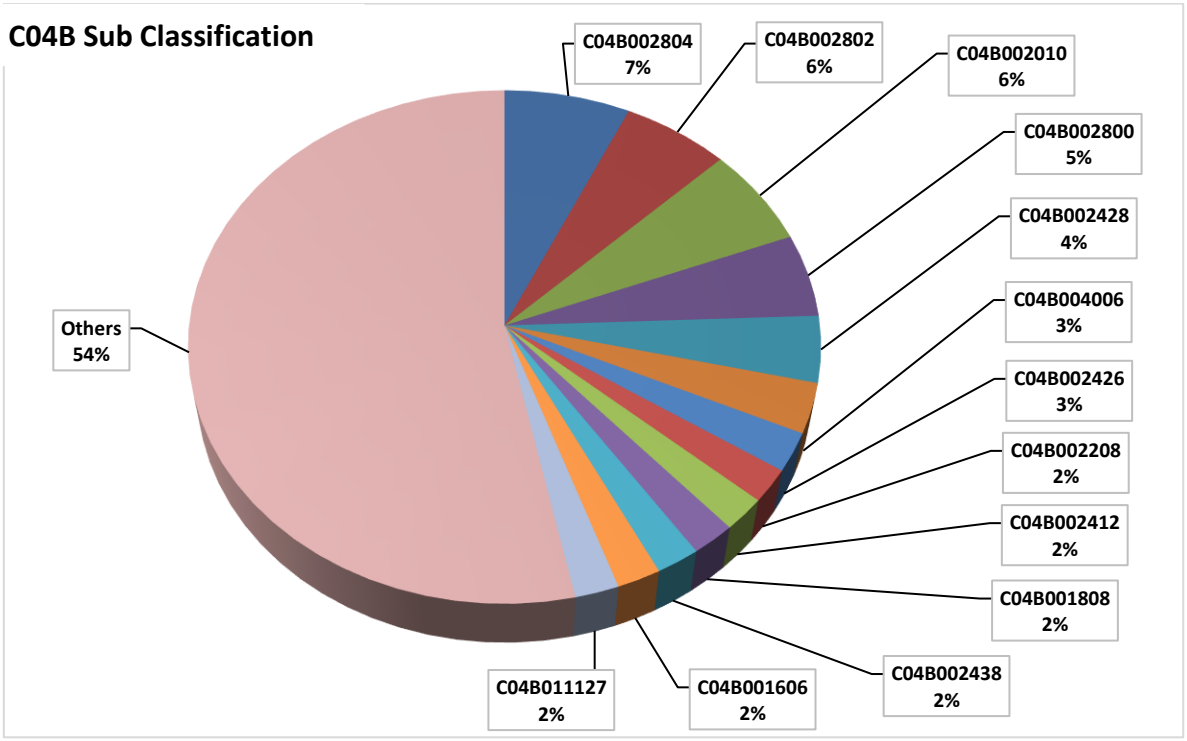


INSIGHT:

Majority of patent applications were assigned with IPC "**C04B**" related to Lime; Magnesia; Slag; Cements; Compositions Thereof, e.g. Mortars, Concrete or like Building Materials; Artificial Stone; Ceramics; Based Refractories; Treatment of Natural Stone.

3.6 INTERNATIONAL PATENT SUB-CLASSIFICATION BASED TREND

The below graph represents sub-classes pertaining to one of the top/main patent classes.



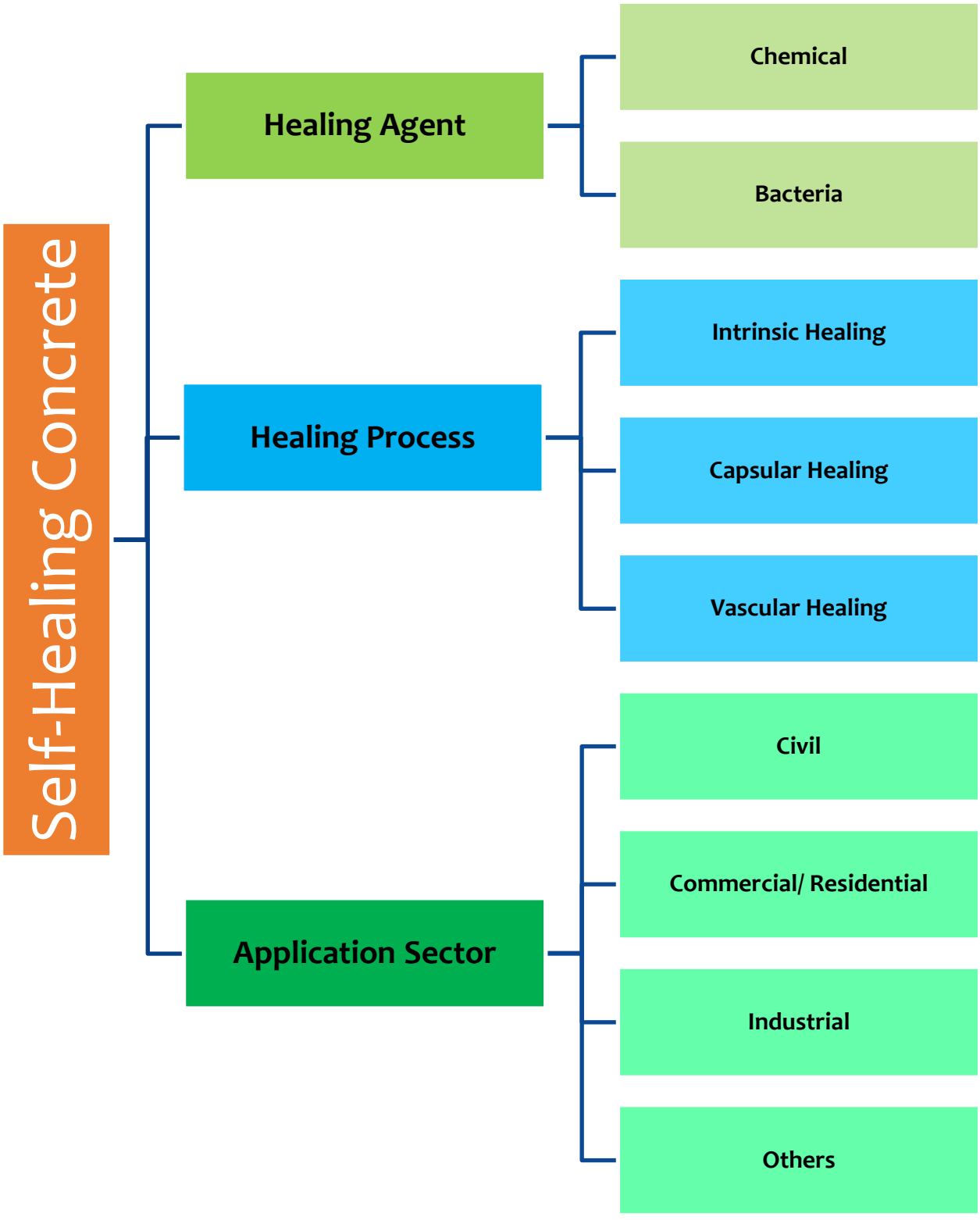
INSIGHT:

"**C04B002804**" emerged as major subclass which relates to Portland cements.

3.1 KEY TECHNOLOGICAL TRENDS

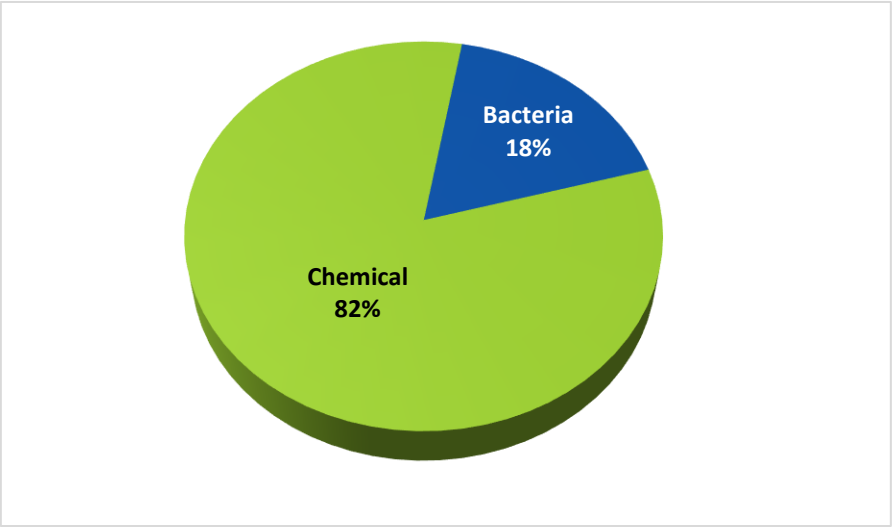
3.1.1 TAXONOMY DEVELOPED FOR BUCKETING OF RELEVANT PATENT DOCUMENTS

A set of 106 patent families were analyzed in depth to identify the focus areas of the patents related to Self-Healing Concrete.



3.1.2 DISTRIBUTION OF PATENTS/APPLICATIONS PERTAINING TO HEALING AGENT USED IN SELF-HEALING CONCRETE

Below representation shows the dissection in terms of healing agent used in the self-healing concrete compositions.

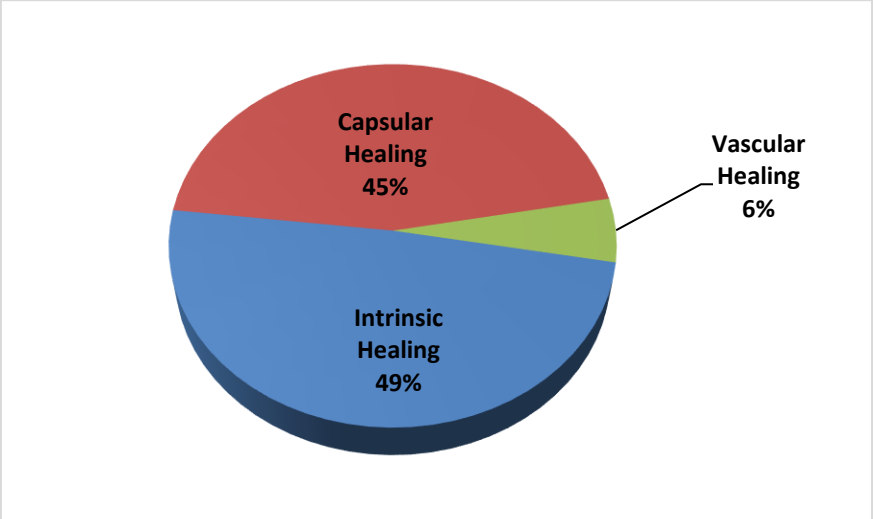


INSIGHT:

As evident from the graph, maximum number of patents/applications focused on chemical healing agents (82%).

3.1.3 DISTRIBUTION OF PATENTS/APPLICATIONS PERTAINING TO HEALING PROCESS OF SELF-HEALING CONCRETE

This category deals with patents/applications pertaining to the dissection of healing process of self-healing concrete.

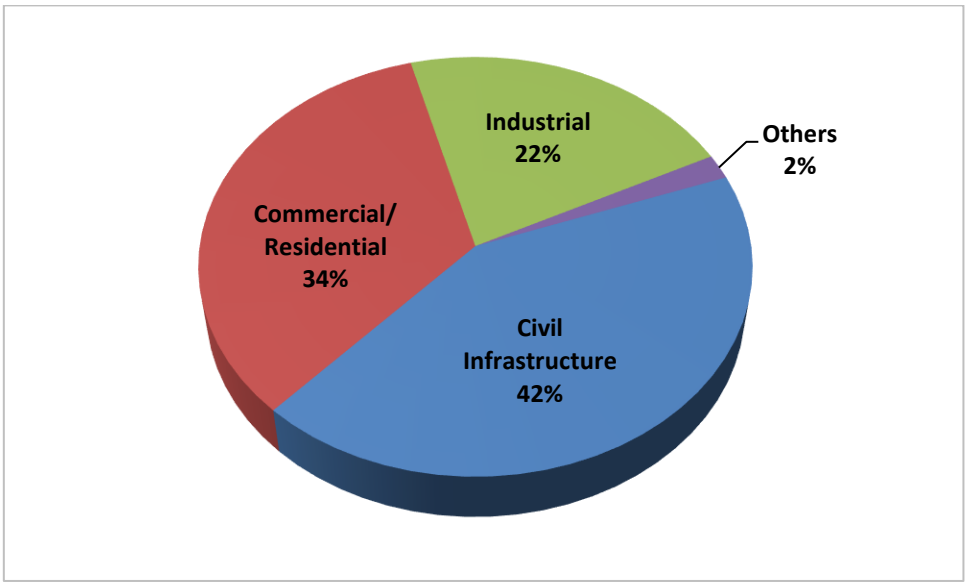


INSIGHT:

As evident from the graph, 49% of patent filings disclosed intrinsic healing process while 45% of patent filings disclosed capsular healing process.

3.1.4 DISTRIBUTION OF PATENTS/APPLICATIONS BASED ON APPLICATIONS OF SELF-HEALING CONCRETE

Below representation shows dissection of application sector of self-healing concrete materials.



INSIGHT:

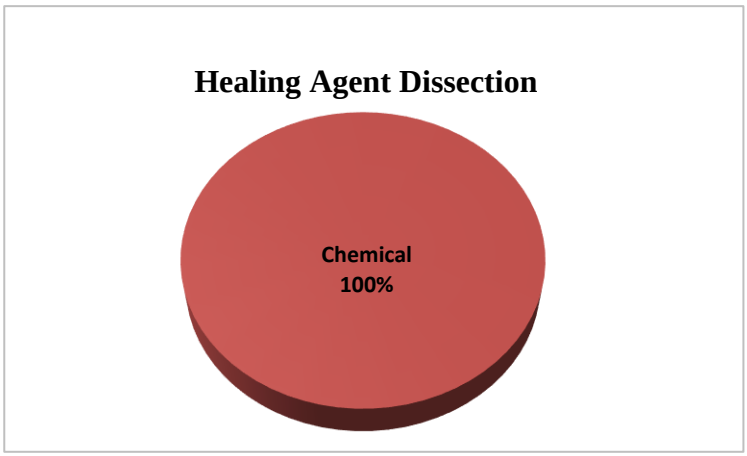
As evident from the graph, 42% of patent filings focused on usage of self-healing concrete in civil infrastructure followed by commercial/residential (34%) and industrial (25%) usage.

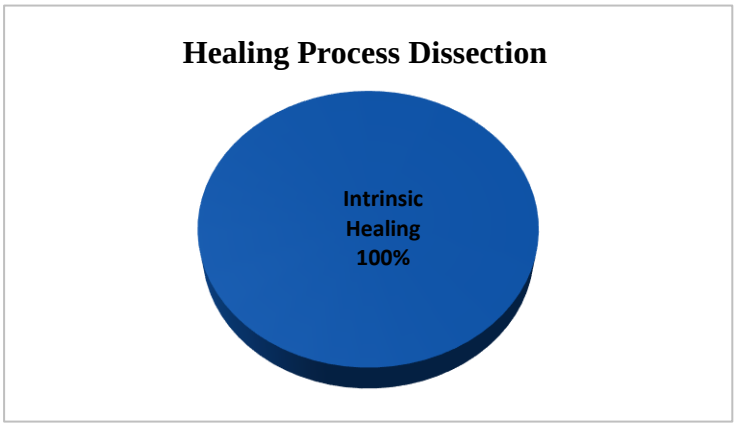
4. Patent Portfolio Analysis

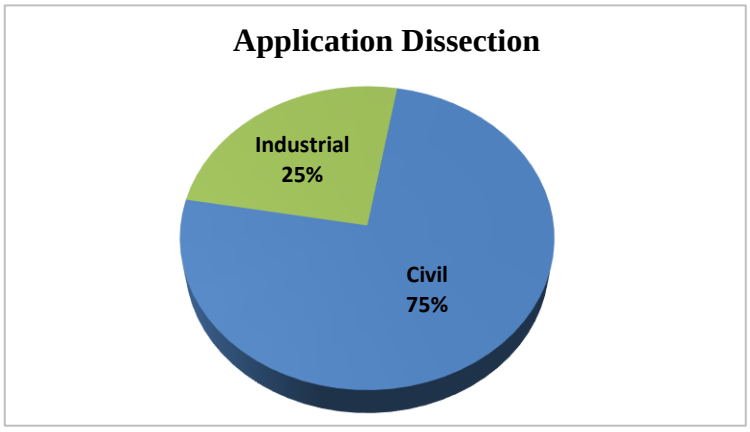
4.1 Patent Portfolio Analysis – INTCHEM CO LTD

Company Profile

- Intchem Co Ltd is a leading South Korea based company manufacturing and exporting self-healing concrete materials for construction industry.







Key Patents – INTCHEM CO LTD

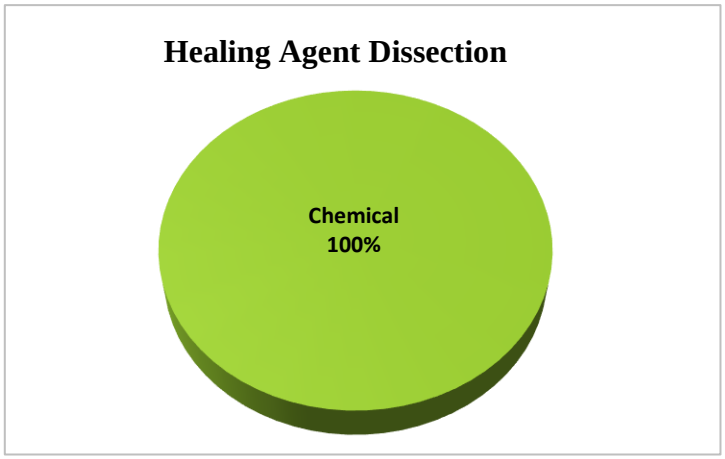
Patent No.	Key Features
KR1966101B1	The patent document relates to a self-healing composition comprising a cement binder, the hybrid self-healing admixture and its preparation. The hybrid self-healing admixture promotes the crystal growth to enhance the self-healing performance of concrete composition in civil infrastructure constructions. Self-healing binder composition comprising a cured admixture, cement 90-94% by weight; CSA (Calcium Sulphur Aluminate) 2 ~ 5% by weight; Bentonite 0.5 to 3% by weight; Crystal growth promoting hybrid self-healing admixture 2-7% by. The self-healing concrete composition exhibited intrinsic healing process.
KR1843816B1	The patent document related to Self-healing cement binder composition with fusion of an organic and inorganic based self-healing admixture. The organic based admixture consisting of cellulose, sodium salt and calcium acetate. The admixture grinded and pulverized with chlorosilane addition. The inorganic based self-healing admixture consists of silica and alkali sulphates. The patent discloses the intrinsic healing process of self-healing admixture for civil constructions.

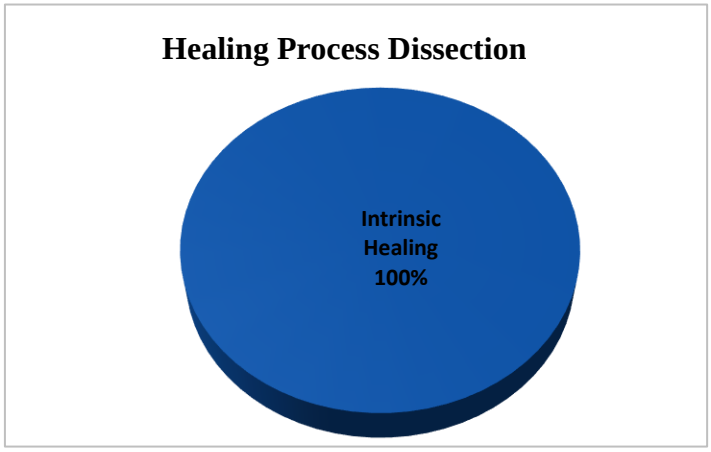
For sources of information, please refer to **Appendix 1**

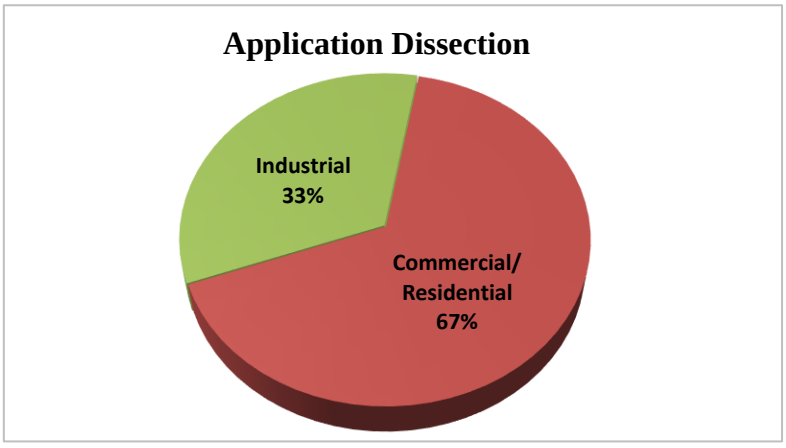
4.2 Patent Portfolio Analysis – SUMITOMO OSAKA CEMENT CO LTD

Company Profile

- Sumitomo Osaka Cement Co. Ltd. is a leading Japan based cement production company.
- The company manufactures Cement-Related Products and sells repairing and reinforcing products for concrete structures; and secondary products of concrete.







Key Patents – SUMITOMO OSAKA CEMENT CO LTD

Patent No.	Key Features
JP05278265B2	The patent document relates to a self-healing concrete admixture composed of granules comprising cement, water in an amount less than the theoretical water content required for the hydration of the cement, and magnesium hexafluorosilicate. The invention discloses an intrinsic healing process of the self-healing concrete admixture and can be applied to various concrete structures in civil engineering not only building sector.
JP2012153577A	The patent document relates to a self-healing concrete admixture composed of cement granules having a mean particle diameter of 30 to 50 μm, urea and fibre, water in an amount less than the theoretical water content required for the hydration of the cement, and magnesium hexafluorosilicate. The invention discloses an intrinsic healing process of the self-healing concrete admixture and can be applied to various concrete structures in civil engineering not only building sector.

For sources of information, please refer to **Appendix 1**

5. Analysis of Key Granted Patents/Patent Applications Assigned to Educational Institutes and Other Companies

5.1 Granted Patents/Patent Applications – TONJI UNIVERSITY

Patent No.	Key Features
CN107445564A	The patent document relates to an alkali gel encapsulated microbial self-healing agent and application thereof. The self-healing agent comprises a component A and a component B. The component A is obtained by mixing and stirring of a nutritional ingredient, a low-alkali gel medium and water uniformly mixing with a concentrated bacillus solution. The component B is a mixture of urea and anhydrous calcium nitrate. The microbial self-healing agent is added to a dry-mixed cement mortar and used for self-healing of gaps of cement. The invention discloses a capsular healing process in applications like petroleum engineering and geology engineering.
CN105565689B	The patent document relates to a method for preparing self-healing concrete system with enhanced autolysis. The system consists of dicalcium silicate repair material, the concrete cementitious material, aggregate, and water from mixing the microspheres obtained by solvent casting, concrete, 8 ~ 12wt% of binder. The invention discloses capsular based healing process and the material can be used in commercial and residential building constructions.

5.2 Granted Patents/Patent Applications – Other Universities and Companies

Patent No.	Key Features
CN109180044A South China University of Technology	The patent application discloses a polystyrene microcapsules self-repair concrete structure wherein self repair polystyrene capsule and PVA fibre uniformly incorporated. The microcapsules have anhydrous sodium metasilicate as core material and cyst material is polystyrene. The present invention can improve the crack resistance of concrete structure of building material in construction industry to improve the safety of the structure of concrete, durability and economy.
CN108483964A Wuhan University of Technology	The patent application relates an invention belongs to the field of electromagnetic induction concrete crack self-repair diisocyanate microcapsule and a preparation method thereof. The microcapsules have diisocyanate as a core material and the mixture of petroleum resin, paraffin, polyethylene wax and magnetic iron powder as a capsule wall. The diisocyanate inside the capsule flows out and is diffused to enter into the cracks, a curing reaction occurs with water inside the concrete and the cracks are repaired in time and prolong the concrete service life.
US20190106717A1 Biomason Inc.	The patent application relates to engineered living marine cement with self-healing capacity and its production method. ELMc involves the development of living biological concrete and/or concrete-like materials that is utilized for marine and other applications. ELMc materials have the capacity to self-heal (e.g., maintenance free), mitigating common structural degradations to traditional marine concretes that result in significant maintenance and/or replacement costs.

6. Appendix

6.1 Appendix A: Sources

- A Review of Self-healing Concrete Research Development
- Self Healing in Concrete Materials
- SELF-HEALING CONCRETE
- https://www.ugent.be/ea/structural-engineering/en/research/magnel/research/research3/selfhealing
- Self-Healing Concrete: Definition, Mechanism And Application In Different Types Of Structures Architecture
- Self-Healing Concrete in Commercial Construction
- https://www.soc.co.jp/sumitomo_e/about/
- http://www.intchem.com/bbs/page.php?hid=mn1_1
- https://www.alliedmarketresearch.com/self-healing-concrete-market
- https://www.globenewswire.com/news-release/2019/04/24/1808765/0/en/Self-healing-Concrete-Market-Size-Soaring-at-26-4-CAGR-to-Reach-US-1-3-Billion-by-2025.html
- https://www.prnewswire.com/news-releases/self-healing-concrete-market-to-reach-1-375-08-bn-globally-by-2025-at-26-4-cagr-amr-300822685.html
- Self-Healing Concrete: The Future of Construction
- Self-healing cement-based materials: an asset for sustainable construction industry
- https://materialdistrict.com/article/living-self-healing-concrete/

6.2 Appendix B: IPC Definitions

IPC	Definition
C04B	LIME; MAGNESIA; SLAG; CEMENTS; COMPOSITIONS THEREOF, E.G. MORTARS, CONCRETE OR LIKE BUILDING MATERIALS; ARTIFICIAL STONE; CERAMICS; BASED REFRACTORIES; TREATMENT OF NATURAL STONE
C04B 28/00	Compositions of mortars, concrete or artificial stone, containing inorganic binders or the reaction product of an inorganic and an organic binder, e.g. polycarboxylate cements
C04B 28/02	containing hydraulic cements other than calcium sulfates
C04B 28/04	Portland cements
C04B 20/00	Use of materials as fillers for mortars, concrete or artificial stone according to more than one of groups C04B 14/00-C04B 18/00 and characterised by shape or grain distribution; Treatment of materials according to more than one of the groups C04B 14/00-C04B 18/00 specially adapted to enhance their filling properties in mortars, concrete or artificial stone; Expanding or defibrillating materials (reinforcing elements for building E04C 5/00)
C04B 20/10	Coating or impregnating
C04B 24/00	Use of organic materials as active ingredients for mortars, concrete or artificial stone, e.g. plasticisers
C04B 24/12	Nitrogen containing compounds
C04B 24/26	obtained by reactions only involving carbon-to-carbon unsaturated bonds
C04B 24/28	obtained otherwise than by reactions only involving carbon-to-carbon unsaturated bonds
C04B 22/00	Use of inorganic materials as active ingredients for mortars, concrete or artificial stone, e.g. accelerators
C04B 22/00	Use of inorganic materials as active ingredients for mortars, concrete or artificial stone, e.g. accelerators
C04B 22/08	Acids or salts thereof
C04B 18/00	Use of agglomerated or waste materials or refuse as fillers for mortars, concrete or artificial stone; Treatment of agglomerated or waste materials or refuse, specially adapted to enhance their filling properties in mortars, concrete or artificial stone (reinforcing elements for building E04C 5/00)

C04B 18/08	Flue dust
C04B 40/00	Processes, in general, for influencing or modifying the properties of mortars, concrete or artificial stone compositions, e.g. their setting or hardening ability (by selecting active ingredients C04B 22/00-C04B 24/00; hardening of a well-defined composition C04B 26/00-C04B 28/00; making porous, cellular or lightening C04B 38/00)
C04B 40/06	Inhibiting the setting, e.g. mortars of the deferred action type containing water in breakable containers
C08F	MACROMOLECULAR COMPOUNDS OBTAINED BY REACTIONS ONLY INVOLVING CARBON-TO-CARBON UNSATURATED BONDS
B01J	CHEMICAL OR PHYSICAL PROCESSES, E.G. CATALYSIS OR COLLOID CHEMISTRY; THEIR RELEVANT APPARATUS
C12N	MICROORGANISMS OR ENZYMES; COMPOSITIONS THEREOF (BIOCIDES, PEST REPELLANTS OR ATTRACTANTS, OR PLANT GROWTH REGULATORS CONTAINING MICROORGANISMS, VIRUSES, MICROBIAL FUNGI, ENZYMES, FERMENTATES, OR SUBSTANCES PRODUCED BY, OR EXTRACTED FROM, MICROORGANISMS OR ANIMAL MATERIAL
C12P	MEASURING ELECTRIC VARIABLES; MEASURING MAGNETIC VARIABLES
B32B	FERMENTATION OR ENZYME-USING PROCESSES TO SYNTHESISE A DESIRED CHEMICAL COMPOUND OR COMPOSITION OR TO SEPARATE OPTICAL ISOMERS FROM A RACEMIC MIXTURE
C08K	USE OF INORGANIC OR NON-MACROMOLECULAR ORGANIC SUBSTANCES AS COMPOUNDING INGREDIENTS (PAINTS, INKS, VARNISHES, DYES, POLISHES, ADHESIVES)

Delhi | Noida | Mumbai | Pune | Bengaluru | Hyderabad | Indore | Jalandhar | Chennai
US | Bangladesh | Myanmar | Vietnam | Nepal | Malaysia | Sri Lanka

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Contact Person

Tarun Khurana

iiprd@iiprd.com, info@khuranaandkhurana.com

Contact No.: +91-120-4296878, 2399113, 2399010

Contact Details

Noida (NCR) Office – Head Office

E-13, UPSIDC Site – IV, Behind Grand Venice, Kasna Road, Greater Noida, 201308

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