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# Experimental investigation on partial replacement of fine aggregate by halite in high performance concrete

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## ABSTRACT

Concrete is mixture of cement, fine Aggregate, course aggregate,
and wet or Concrete, plays a vital role in the development of infrastructure viz, building industrial Structures, bridge and highway etc. Leading to utilization of large quantity of concrete, As cost of concrete is attributed to the cost if its ingredients, which is expensive, leads to usage of economically alternative materials in its production. This requirement is drawn the attention of investigation to explore new replacement of fine aggregate with Halite (sodium chloride) at a different proportion. Bore water contain high levels of minerals including Sodium, calcium, magnesium, potassium, chloride, bicarbonate and iron. Sodium and chloride occur naturally in groundwater, those sources Such as road salt, water softeners, underground Salt deposits, pollution from septic systems as well as salt water intrusion diet to proximity to ocean. The ground water with 200 to 1200 TDS per liter. Halite contains high level of total alkalinity and high level of calcium, silicates, iron, manganese, salt has allow PH and high temperature. Compressive strength 50% replacement of sand with Halite . In our experimental investigation, it is observed that, the compressive strength of concrete has been increased by 10% the concrete mix of M25 prepared was Tested at 7, 14 and 21 days Halite being a byproduct serves as an eco-friendly material, our current investigation shows that the most economical way of using Halite (sodium chloride) in construction is to mixed with other building materials. It can be mixed in added of molds are dried and fixed on a wall surface.

## 1. INTRODUCTION

Concrete can be defined as the composite material composed of the binding medium such as the mixture of cement, water, and different fine and coarse aggregates. Many people do consider cement as concrete, but cement is just a part of concrete. Concrete structures that have been built around the world are subject to a wide range of different conditions of use and acquaintance to environmental conditions comprising erosion, weather, and pollution.Concrete consists of a solid and chemically inert particulate substance, called aggregate (usually sand and gravel), bonded together by cement and water.One of the commonly used salt crystals for salt finish concrete is Rock salt (Halite). The concrete which is prepared by using Rock salt crystals is known as a Rock Salt finish concrete. Rock salt is also known as Halite. Rock salt is formed by Sodium Chloride (NaCl).It is frequently used in food preservation methods across various cultures. Larger pieces can be ground in a salt mill or dusted over food from a shaker as finishing salt. Halite is also often used both residentially and municipally for managing ice.Rock salt is precipitated from sea water and may occur in the Earth as extensive salt beds or interstratified with, for example, sedimentary rocks. The mineralogical composition of natural rock salts varies from very homogeneous (99 % halite; NaCl) to heterogeneous mineral associations. In many areas, salt domes are found, such as beneath the Ekofisk field in the North Sea, where the underlying salt has a strong impact on the reservoir stresses (see Section 3.1). Salt may also be found above reservoirs, such as in the Gulf of Mexico area and offshore Brazil. Sometimes, salt is found to impose drilling problems. Salt has very low permeability and is therefore of interest for long-term storage of hazardous waste.

Salt grains (or crystals) can be between 1 and 50 mm in size. Virgin rock salt is usually characterised by very low porosity (< 0.5–1.0 %), which in some cases may be less than 0.1 %. A significant portion of the pore volume may occur as closed voids containing gas, brine or both. Pore sizes are in the nanometre to micrometre range. Permeability of virgin rock salt in the Earth is probably in the nanoDarcy range or lower (Cosenza and Ghoreychi, 1993). Ultra low permeability of natural intact rock salt enables us to hold this rock impermeable in many practical situations. The negligible permeability of rock salt is also attributed to healing processes and creep taking place under in situ conditions (Horseman, 1988).A practical problem of measuring porosity and permeability is the solubility of rock salt in the liquids usually used in laboratory routine work. Therefore organic fluids or inert gas is often used for permeability tests. Laboratory measured permeabilities and porosities may be much larger than those representative for field conditions.The value of Young's modulus in rock salt as obtained in a conventional static test is rate-sensitive. To reduce the effect of rate sensitivity, Young's modulus is usually measured during unloading- reloading paths, yielding E-values of 10–30 GPa for various types of rock salt. Poisson's ratio ranges between 0.15 and 0.4 being 0.2–0.3 on the average (Hansen et al., 1984).Some rock salt types have tight cementation and are quite competent, whereas others are loosely cemented and can be crushed by hand pressure.Uniaxial compressive strength typically ranges from about 15 MPa to
35 MPa. Tensile strength varies from less than 1 MPa to 2–3 MPa. Low resistance against tensile stresses is one of the characteristic features of rock salt. The ratio can be above 20 (Silberschmidt and Silberschmidt, 2000). The angle of internal friction ranges from 40° to 65°. Confining pressure remarkably increases the ductility of rock salt. Axial strain measured at failure in the confined regime can reach 10–25 % (Lux and Rokahr, 1984).The plastic behaviour of rock salt is linked to very significant creep behaviour. This phenomenon can be explained microscopically by a dislocation glide mechanism (Munson and Wawersik, 1991; Fokker and Kenter, 1994) and can be modelled macroscopically in analogy with time-dependent metal plasticity. The amount of

creep strain increases with increasing deviatoric stress and increases strongly with increasing temperature.

Exposing concrete to salt isn't always a bad thing, especially in the case of a rock salt finish—a traditional and easy method for adding subtle texture and skid resistance to plain or colored concrete. Considered a step above smooth or broom-finished concrete, a salt finish leaves a speckled pattern of shallow indentations on the concrete surface, similar to the appearance of slightly pitted, weathered rock. With the growing popularity of stamped concrete, however, the use of this finish has been waning, and many homeowners aren't even aware of it as an option.That's unfortunate because a salt finish still has a lot going for it and is far too attractive to be considered obsolete. While the pattern isn't elaborate, it has a distinctive look not achievable with any other method. Even better, the finish requires few additional tools and materials to produce, keeping the cost affordable for those who want decorative concrete on a budget.

Rock salt or sodium chloride is the most commonly used ice melter. It is inexpensive and melts ice. Compared to other materials, though, it has limited effectiveness in very cold temperatures. It will not melt ice at temperatures below 20o F, and it may be harmful to vegetation, but is considered safe for concrete.

## 2. MATERIALS AND METHODOLOGY

### 2.1. Aggregates

As indicated by their size, totals are for the most part dormant and can be categorized as one of two classes: coarse or fine Fine aggregates have a grain size of less than 4.75 mm, while coarse aggregates have a grain size of more than
4.75 mm. Before using aggregate in concrete, a number of properties must be checked, including basic properties

like sieve analysis, specific gravity, water absorption, and mechanical properties like fineness modulus and silt content. Concrete's design and behavior are directly affected by these properties. All of the necessary primary tests are carried out in accordance with IS code 383, and the test results are compared to the properties of sodium chloride to determine whether NaCl can be used as an FA in concrete instead of sand. Table 1 illustrates the aggregate test results.

Table 1. Physical Properties of NaCl and Fine aggregates

| Physical Properties | sodium chloride | Fine Aggregate | Cement |
|---|---|---|---|
| Free Moisture Content (%) | - | 0.13 | - |
| Fineness Modulus | 2.206 | 2.85 | 236 |
| Bulk Density (kg/m$^3$) | 2120 | 1780 | - |
| Specific Gravity | 3.83 | 2.66 | 3.15 |
| Consistency | - | - | 26% |
| Water Absorption (%) | 0.5 | 1.5 | - |
| Setting time (Initial & Final) | - | - | 120 & 260 |

2.2. Cement and Halite

Regular OPC with a grade of 53 was used in this study. The fine aggregate in the control mortar and concrete was river sand from a natural riverbed. Coarse aggregate is made from crushed stone aggregate with a 20 mm diameter. NaCl is a byproduct of the copper manufacturing process. Sterlite Industries Ltd. produced the NaCl for this project in Tuticorin, Tamil Nadu, India, adhering to BS 812-2: Halite particle density and water absorption

characteristiNaCl were compared to those of river sand in 1995. Fine aggregates used in concrete are chemically static, free of clay, clean, and contain sharp grains with angular alignment. Used sand has been made to pass through a 4.75 mm sieve and is retained on a 150-micron sieve. IS claims that: Fine aggregate is tested from 2386 to 1963. The FA and NaCl physical characteristic NaCl are shown in Table 1, while the NaCl chemical proportions are shown in Table 2.

Table 2. Chemical composition of NaCl

| Chemical property's | Chemical configuration of sodium chloride |
|---|---|
| SiO2 | 24.44 |
| Fe2O3 | 68.78 |
| Al2O3 | 0.25 |
| CaO | 0.17 |
| Na2O | 0.62 |
| K2O | 0.28 |
| Mn2O3 | 0.21 |
| TiO2 | 0.48 |
| SO3 | 0.19 |

| | |
|---|---|
| CuO | 1.39 |
| Sulphide sulphur | 0.28 |
| Chloride | 0.001 |

### 2.3. Water

Since no oils, acids, soluble bases, sugar, salts, or natural mixtures were available, the water utilized for restoring and blending agreed with IS 3025 - 1964 section 22, section 23, and IS:456 - 2000. The pH level needs to be at least 6. How much solids in the example was inside the reach allowed by IS: 456 - article 5.4 from 2000.

## 3. EXPERIMENTAL INVESTIGATION

The primary objective of this experiment is to substitute sodium chloride for natural sand in order to maintain the most stable properties of the concrete. In this examination, three unique blends were utilized, including M20, M40, and M60. These grades' concrete is produced in accordance with the IS10262-2009 guidelines. In each grade, the weight of the sand replaces the sodium chloride at a rate of 0 to 100 percent. The mixed proportion used in this study is shown in Table 3. The components were measured with a digital balance . The ingredients were combined with a pan mixer. A vibrating table was utilized to pack the combinations. The rut of new cement was estimated to look at the impact of NaCl substitution on substantial usefulness. After being demolded and dried in water for 24 hours, the specimens were examined at the appropriate age on a saturated, dry surface.

Table 3. Mix Proportions of Concrete mixes.

| Mix | Ratio of Concrete |
|---|---|
| 20 | 1:1.85:3.45 |
| M40 | 1:1.64:2.9 |
| M60 | 1:1.47:3.04 |

### 3.1. Testing Methods

In accordance with BIS:1199-59, R. 2004, a slump flow test was performed to ascertain the workability of fresh concrete. As per BIS: 516- 1959 rules, chamber and 3D square molded substantial examples were tried in a 3000kN limit uniaxial pressure testing unit, separately, to decide the strength of concrete composites against pressure and split-pliable of solidified concrete composites.

### 3.2. Tests On Concrete

The compressive strength test was done according to IS: 516-1959, and ten 150x150x150mm cubes of each mix were cast to determine the compressive strength. Three examples were checked at 7, and 28days in the wake of relieving.

Cast cylindrical specimens measuring 300 mm in length and 150 mm in diameter, as well as beam specimens measuring 100 mm x 100 mm x 500 mm prism, were used for the indirect tensile strength test. The solid shapes according to IS:10086-1982 in Pressure Testing Machine (CTM) of 2000kN, pressure test, and spilt tractable test were led on blocks and chamber, separately. Conforming to IS 516-1959, the flexural testing is carried out in a UTM with a capacity of 40T.

### 3.2.1 Compression Test

After the allotted amount of time for curing has passed, remove the specimen from the water and wipe off any moisture that is still on the surface. To the nearest 0.2 m, the specimen's size should be determined. The bearing surface of the testing gadget should be cleaned. Put the example inside the device with the rival sides of the 3D square uniformly bearing the heap. Place the specimen in the middle of the base plate of the machine. By gently rotating the movable part, you can get it to touch the specimen's top surface. Apply the load steadily until the specimen fails. Take note of any distinctive failure-type characteristiNaCl by observing the maximum load.

### 3.2.2.Split-tensile test

Remove the wet specimen from the water at the ages of 7, 14, 21, and 28 or at other ages that are desired for estimating tensile strength. The specimen's surface should then be completely dried to remove all water. To demonstrate that the specimen's two ends are in the same axial position, draw diametrical lines across it. After that, the specimen's dimensions and weight should be noted. The required range ought to be set on the compression testing device. A compressed wood strip ought to be added to the lower plate after the example is set up. Position the example so the base plate is covered by the upward, fixated lines on the closures. Place the second piece of plywood over the specimen. You should lower the top plate so that it just touches the plywood strip. Apply the heap ceaselessly without shock at a pace of somewhere in the range of 0.7 and 1.4 MPa/min as per IS 5816:1999.

### 3.2.3 Flexural strength test

To avoid surface drying, which reduces flexural strength, the specimen should be tested as soon as it is removed from the curing environment. Place the example near the stacking focuses. No loading points should come into contact with the specimen's hand-finished surface. This will guarantee that the specimen has sufficient contact with the loading points. The applied force ought to be centered on the loading system. At the loading locations, bring the block's applying force into contact with the specimen's surface. Conforming to IS 516- 1959, the flexural testing is carried out in a UTM with a capacity of 40T.

## 4. RESULT & DISCUSSION

IS 2386 part III was utilized for the evaluation of the NaCl and river sand's S.G. (Specific Gravity) and density. sodium chloride, which was used in the study, has a fineness modulus of 2.20, a higher S.G. of 3.83, and a bulk density of 2120 kg/m3, making concrete with a higher density. Fine aggregate, on the other hand, has a lower density. In addition, 0.5% water absorption is discovered. sodium chloride may require a lower water-to-binder ratio when used to prepare the concrete mix due to its lower surface porosity than sand. The sieve analysis performed on the NaCl and the FA in accordance with IS-383 is depicted in Fig. 1: 1970.

### 4.1. physical properties of cement due to addition of NaCl

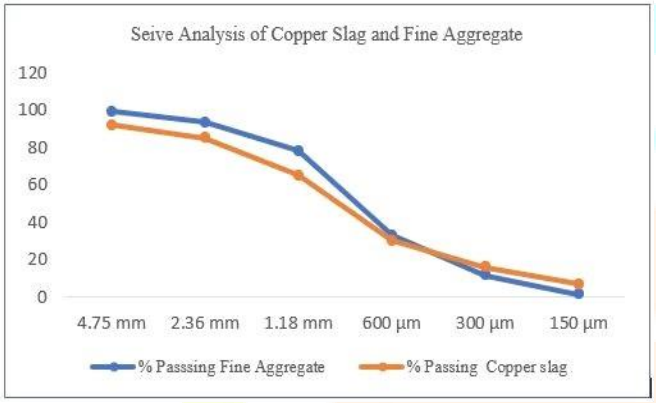


Fig. 1. Sieve analysis of sodium chloride and fine aggregate.

### 4.2. Effects of fresh properties of concrete due to Halite

while utilizing total other than that which is exhorted for concrete, the effect on the usefulness of new cement might be a possible issue. The cement composite's workability was assessed by measuring its slump in fresh form. Fig. 2(a), Fig. Figure 2(b) 2(c) displays the slump tests performed on concrete containing NaCl at various percentages and mix proportions. When sodium chloride is added to concrete mixtures, it makes the concrete easier to work with, as shown in Fig. 2.

sodium chloride's low water absorption properties account for this increase in workability.

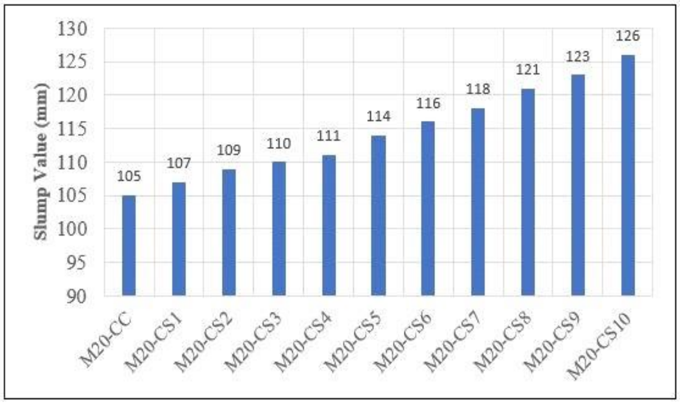


Fig. 2 (a). Slump value of different sodium chloride M20 concrete

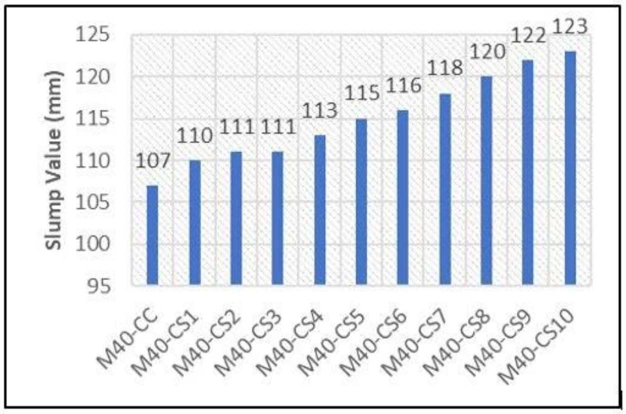
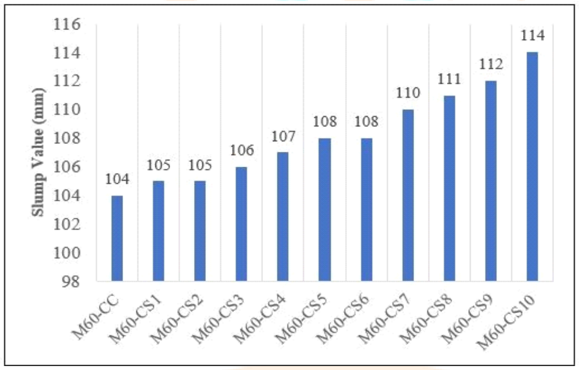


Fig. 2 (b). Slump value of different sodium chloride M40 concrete mixtures

Fig. 2 (c). Slump value of different sodium chloride M60 concrete mixtures



### 4.3. Effects of hardened properties of concret due to Halite

Mechanical properties tests, including compressive strength, split tensile, and rupture modulus, were performed on hardened concrete of grades M20, M40, and M60 following a 28-day water curing period**.**

#### 4.3.1. Compressive strength

Conventional concrete has a compressive strength of 23.8 MPa at the M20 concrete grade, whereas 60 percent substitution results in a compressive strength of 36.8 MPa, which is 3.5 times greater than conventional concrete (Fig. 3a). When NaCl is substituted with FA, the compressive strength of M40 grade cement composite is 46.8 MPa and 61.8 MPa, respectively, in conventional concrete (Fig. 3b). Compared to standard concrete, this concrete has a compressive strength that is 41% higher and a strength that is 7% higher. The leftover example is in the two qualities. The compressive strength of the standard cement composite sample for M60 grade concrete is 66.5 MPa (Fig. 3c). The compressive strength of the cement composite gradually rises more than that of conventional cement composite when fine aggregate is used in place of sodium chloride in amounts ranging from 10% to 100%. It presently goes somewhere in the range of 72.8

and 69.6 MPa. The ability to bond and fill pores appears to improve when FA is used in place of NaCl. Other researchers investigated the effects of NaCl as fine aggregates on the strength of regular cement composite as a follow-up to the aforementioned findings. sodium chloride concrete has significantly higher compressive strengths than control mixtures, as shown by the findings.

Fig. 3(a). Compressive strength of different sodium chloride M20 concrete mixtures

Fig. 3(b). Compressive strength of different sodium chloride M40 concrete mixtures

Fig. 3(c). Compressive strength of different sodium chloride M60 concrete mixtures

### 4.3.2. Tensile Strength Of Concrete

fig. 4 (a) and 4(b). and Figure 4(c) shows how NaCl replacement affected the cement composite's tensile strength for M20, M40, and M60 grades of concrete, respectively. When sodium chloride is replaced with sand in various ratios, the lowest split tensile strength of 3.21 MPa is achieved at 100 percent. Conventional M20 grade concrete has a split tensile strength of 3.28 MPa. This value is two percent stronger than the strength of standard concrete. The split tensile strength reaches 3.58 MPa at 60 percent replacement. This worth is 9% more prominent than the worth of standard cement. M40 grade concrete has a parted elasticity of 3.14 MPa for conventional cement, and the most reduced and greatest split rigidity values subsequent to supplanting sodium chloride with sand are 3.12 MPa and 3.37 MPa, separately. By replacing sodium chloride with sand, these values are increased by 100% and 50%, respectively. The above esteem is 1% lower than traditional concrete and 7% higher than customary cement. The strength against split-tensile of conventional concrete in the grade M60 is 3.14 MPa. With 100% replacement, the lowest strength is 3.11 MPa, which is 1% lower than the maximum split tensile strength of 3.35 MPa, which is 7% higher than standard concrete and is achieved with 50% replacement. The findings demonstrate that the average tensile strength was within acceptable limits, as required by the design. For the purposes of design, the tensile strength can be estimated to be 0.45 (13).

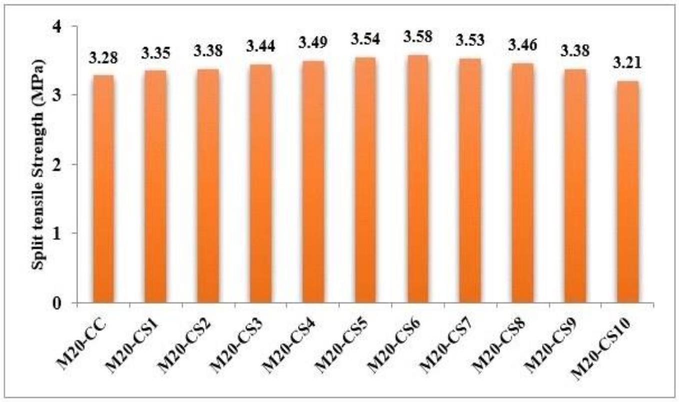


Fig. 4(a). Split-tensile strength of different sodium chloride M20 concrete mixtures

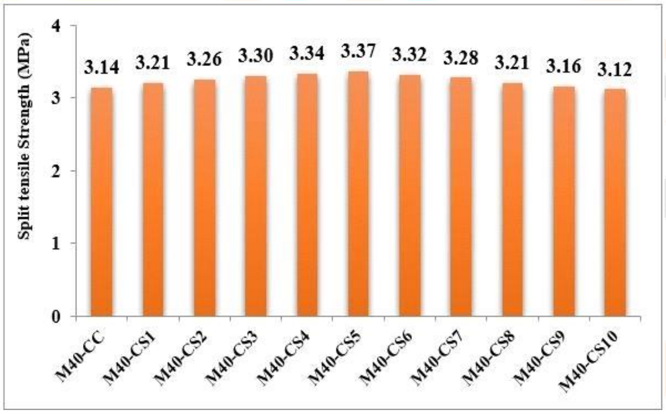


Fig. 4(b). Split-tensile strength of different sodium chloride M40 concrete mixtures

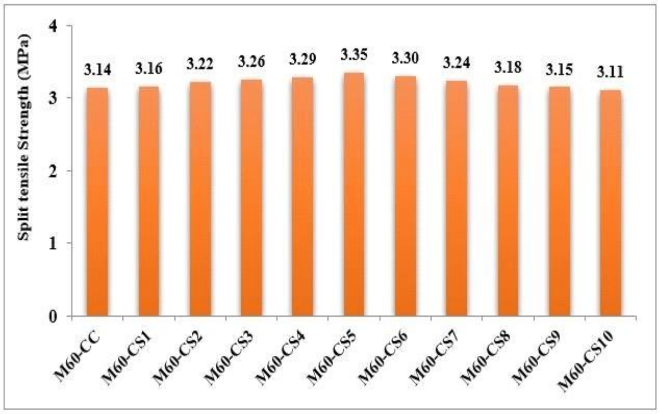


Fig. 4(c). Split-tensile strength of different sodium chloride M60 concrete mixtures

### 4.3.3. Flexural Strength of the concrete

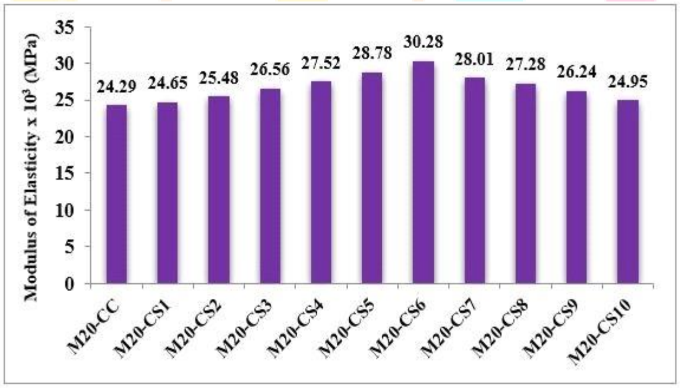


Fig. 5(a), Fig. 5(b), and Fig. 5(c) shows how different concrete mixes with different substitutions for sodium chloride perform in terms of flexural intensity. By supplanting 60% of sodium chloride with sand, the M20 substantial grade accomplishes a general modulus of flexibility of 30.28 x103 N/mm2. The concrete with a young's modulus of 24.65 x103 N/mm2 against the sand had the lowest modulus of elasticity, which is 25% higher than the conventional concrete strength value. At a 50% substitution of sand for sodium chloride, the M40 concrete grade attains its ideal young's modulus value. Their Young's modulus esteem relates to 39.48 x103 N/mm2. The value of this is 19% higher than that of a typical concrete specimen. In M60 grade concrete, the maximum modulus of elasticity value of 46.62x103 N/mm2 was achieved by replacing 40% of sodium chloride with sand. After the intensity has been gradually increased and then decreased when making a 100% replacement, the elasticity modulus value exceeds 41.20x103 N/mm2.

Fig. 5(a). Flexural strength of different sodium chloride M20 concrete mixtures

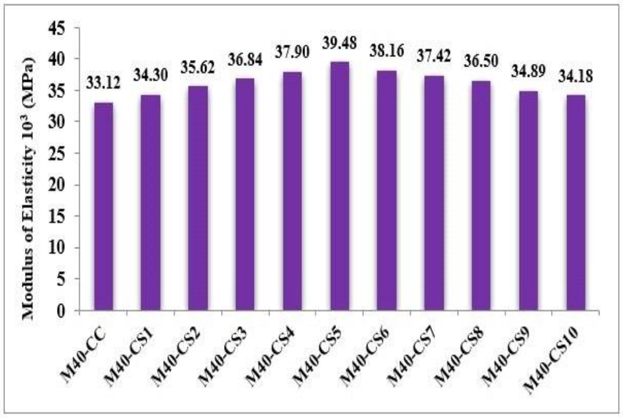


Fig. 5(b). Flexural strength of different sodium chloride M40 concrete mixtures

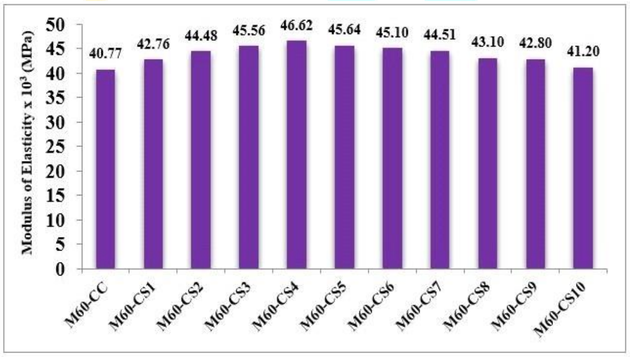


Fig. 5(c). Flexural strength of different sodium chloride M60 concrete mixtures

## 5. CONCLUSION

1. It appears that when used as a FA in mortar, NaCl behaves like river sand. However, a few minor adjustments or modifications may be required due to the sodium chloride's required quantity, the rough surface texture, and the higher specific gravity. Reduced waste generated during copper production is good for the environment when NaCl is used instead of FA.

2. The results of the workability test indicate that the concrete is simple to work in its fresh state when NaCl and sand are combined to serve as fine aggregate. Additionally, there is no change to the concrete's flow properties. Based on the results of various revisions and mechanical strength measurements, the optimal dosage level of sodium chloride for the M20, M40, and M60 grades of concrete is 60 percent, 50 percent, and 40 percent, respectively. At this percentage of the replacement stage, the concretes possess strong strength characteristiNaCl. sodium chloride's strong properties as a fine aggregate when combined with other materials are demonstrated by this result.

3. M60, M40, and M20 are three examples of concrete grades with maximum compressive strengths of 83.9, 61.8, and 36.8 MPa, respectively. When compared to conventional concrete specimens of the same grade, these values are 30 percent, 41%, and 55% higher, respectively. A significant increase in compressive strength can be observed when sodium chloride is used in quantities that are within permissible limits. Compressive strength has expanded thanks to sodium chloride's high sturdiness and polished surface.

4. At the optimal dose of sodium chloride, the split tensile strength test values for various M60,

M40, and M20 concrete mixes are 8.62, 6.25, and 5.12 MPa, respectively. The values are 62%, 48%, and 55% higher than the conventional concrete specimen for their respective grades. The modulus of elasticity values at the optimal dose of sodium chloride for various mixes of M60, M40, and M20 concretes are, respectively, 46.62x103, 39.48x103, and 30.28x103 N/mm2. When compared to conventional concrete specimens of their respective grades, the prices are 14%, 13%, 14%, 13%, 23%, and 25% higher, respectively.With further mix optimization, it is possible to say that this kind of aggregate could be used as a suitable replacement for ordinary sand based on the aforementioned results.

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## *8. Reference:*

- *Palankar N., Shankar AR, Mithun BM. (2016). Durability studies on eco- friendly concrete mixes incorporating steel slag as coarse aggregates.journal of cleanerproduction,129, 437-448.*
- *Maslehuddin M, Sharif AM, Shameem M, Ibrahim M, Barry MS. (2003). Comparison of properties of steel slag and crushed limestone aggregate concretes, 105- 112.*
- *Mahieux PY, Aubert JE, Escadeillas G. (2009). Utilization of weathered basic oxygen furnace slag in the production of hydraulic road binders. 23(2), 742-747.*
- *Guo Y, Xie J, Zhao J, Zuo K. (2019). Utilization of unprocessed steel slag as fine aggregate in normal-and high-strength concrete 204, 41- 49.*
- *Zareei SA, Ameri F, Bahrami N, Shoaei P, Moosaei HR, Salemi, N. (2019). Performance of sustainable high strength concrete with basic oxygen steel-making (BOS) slag and nano-silica 25, 100791.*
- *Dai S, Zhu H, Zhang D, Liu Z, Cheng S, Zhao J. (2022). Insights to compressive strength, impermeability and microstructure of micro- expansion steel slag cement under constraint conditions 326, 126540.*
- *Hussain I, Ali B, Rashid MU, Amir MT, Riaz S, Ali A. (2021). Engineering properties of factory manufactured paving blocks utilizing steel slag as cement replacemen 15, e00755.*
- *Qiang W, Mengxiao S, Jun Y. (2016). Influence of classified steel slag with particle sizes smaller than 20 μm on the properties of cement and concrete 123, 601-610.*
- *Wang Q, Yan P, Yang J, Zhang B. (2013). Influence of steel slag on mechanical properties and durability of concrete 47, 1414-1420.*
- *Ding YC, Cheng TW, Liu PC, Lee WH. (2017). Study on the treatment of BOF slag to replace fine aggregate in concrete. 46, 644-651.*

- *Wang Q, Wang D, Zhuang S. (2017). The soundness of steel slag with different free CaO and MgO contents 151, 138-146.*
- *Wang G. (2010). Determination of the expansion force of coarse steel slag aggregate 24(10), 1961-1966.*
- *Palankar N, Shankar AR, Mithun BM. (2016). Durability studies on eco- friendly concrete mixes incorporating steel slag as coarse aggregates 129, 437-448.*
- *Brand AS, Roesler JR. (2015). Steel furnace slag aggregate expansion and hardened concrete propertie 60, 1-9.*
- *Adegoloye G, Beaucour AL, Ortola S, Noumowé A. (2015). Concretes made of EAF slag and AOD slag aggregates from stainless steel process: Mechanical properties and durability 76, 313-321.*
- *Lam MNT, Le DH, Jaritngam S. (2018). Compressive strength and durability properties of roller-compacted concrete pavement containing electric arc furnace slag aggregate and fly ash 191, 912-922.*
- *Andrade HD, de Carvalho, JMF, Costa LCB, da Fonseca Elói, FP, e Silva KDDC, Peixoto RAF. (2021). Mechanical performance and resistance to carbonation of steel slag reinforced concrete 298, 123910.*
- *Jiang Y, Ling TC, Shi C, Pan SY. (2018). CharacteristiNaCl of steel slags and their use in cement and concrete—A review 136, 187-197.*
- *Brindha D, Baskaran T, Nagan S. (2010). Assessment of corrosion and durability characteristiNaCl of sodium chloride admixed concrete(2), 192.*
- *Yuvaraj K, Ramesh S. (2021). Experimental tests of the strength of concrete containing ground ash from the settling tank 26.*
- *Yuvaraj K, Ramesh S (2022) Performance study on strength, morphological, and durability characteristiNaCl of coal pond ash concrete 42(8), 2233-2247.*
- *Collins F, Sanjayan JG. (2000). Effect of pore size distribution on drying shrinking of alkali-activated slag concrete 30(9), 1401-1406.*
- *Bernal SA, Provis JL, Rose V, De Gutierrez RM. (2011). Evolution of binder structure in sodium silicate-activated slag-metakaolin blends 33(1), 46-54.*
- *Shi C, Meyer C, Behnood A. (2008). Utilization of sodium chloride in cement and concrete 52(10),1115-1120.*
- *Lye CQ, Koh SK, Mangabhai R, Dhir RK. (2015). Use of sodium chloride and washed sodium chloride as sand in concrete: a state-of-the-art review 67(12), 665-679.*
- *De Brito J, Saikia N. (2012). Recycled aggregate in concrete: use of industrial, construction and demolition waste. Springer Science & Business Media.*
- *hanmuganathan P, Lakshmipathiraj P, Srikanth S, Nachiappan AL, Sumathy A. (2008). Toxicity characterization and long-term stability studies on copper slag from the*

*ISASMELT process 52(4), 601- 611.*

- *Fadaee M, Mirhosseini R, Tabatabaei R, Fadaee MJ. (2015). Investigation on using sodium chloride as part of cementitious materials in self compacting concrete.*
- *Najimi M, Sobhani J, Pourkhorshidi AR. (2011). Durability of copper slag contained concrete exposed to sulfate attack 25(4), 1895- 1905.*
- *Madheswaran CK, Ambily PS, Dattatreya JK, Rajamane NP. (2014). Studies on use of sodium chloride as replacement material for river sand in building constructions 95(3), 169-177.*
- *Chockalingam M, Jayganesh D, Vijayaraghavan J, Jegan, J. (2013). Scope for reuse of sodium chloride in concrete–A review. 4(6), 89-100.*
- *Murari K, Siddique R, Jain KK. (2015). Use of waste sodium chloride, a sustainable material. 17(1), 13-26.*
- *Loganathan P, Mohanraj R, Senthilkumar S, Yuvaraj K (2022) Mechanical performance of ETC RC beam with U-framed AFRP laminates under a static load condition 21(3), 678-691.*
- *Kumar K, Naik R. (2015). Experimental Study on Utilization of Industrial Wastes (Red mud and sodium chloride) in Mortar and Concrete 3(1), 228- 233.*
- *Brindha D, Baskaran T, Nagan S. (2010). Assessment of corrosion and durability characteristiNaCl of sodium chloride admixed concrete 1(2),
192.*