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A Laboratory Study on the Influence of Steel Slag and Potassium Chloride on Improving the Properties of an Expansive Soil for the Foundation Bed

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Abstract: Black cotton soil covers large parts of central and southern India and gives foundation engineers a recurring headache: it swells when it gets wet and shrinks badly when it dries out, and a structure sitting on it can heave or crack long before any load-bearing failure ever happens. This paper reports what happened when such a soil, dug from a site known for this behaviour, was mixed with steel slag - a waste product from steel plants - together with potassium chloride, a simple salt that is known to interfere with the swelling chemistry of montmorillonite clay. Before any treatment, the soil was put through the standard battery of index and strength tests: hydrometer analysis, Atterberg limits, free swell, specific gravity, compaction and CBR. It turned out to be a CH soil with 110% differential free swell, a liquid limit above 83%, and an almost unusable soaked CBR of 1.395%. Steel slag was then fixed at 15% of the dry mix, and potassium chloride was varied from 0 to 2% in half-percent steps. Every one of these five mixes was re-tested for free swell, liquid limit, compaction, soaked CBR and triaxial compressive strength, the last of these at both 7 and 14 days of curing. The numbers moved in a consistent direction: free swell fell from 90% (soil + slag alone) down to roughly 40% at the highest KCl dose, the liquid limit dropped to the low seventies, and density, CBR and triaxial strength all climbed steadily up to 1.5% KCl before easing off slightly at 2%. Soaked CBR rose from 1.395% in the raw soil to close to 8.7% at the best mix, and triaxial deviator stress improved further with longer curing. Taken together, the results point to 15% steel slag with 1.5% potassium chloride as a practical, cheap and waste-reusing way to turn this problematic clay into a workable foundation bed.
Keywords: Expansive soil, Steel slag, Potassium chloride, Soil stabilization, California Bearing Ratio, Free swell index, Triaxial shear strength.

I. INTRODUCTION

A. Expansive Soil

Anyone who has built on black cotton soil knows the frustration: the ground looks perfectly firm in the dry season and then heaves under the same foundation once the rains set in. This behaviour comes down to the clay mineral montmorillonite, whose flaky crystal structure can pull water molecules in between its own layers and expand several times its dry volume. Roughly a fifth of India's land area is underlain by soils of this kind, and similar clays cause the same trouble in parts of Africa, Australia and the southern United States. In practice, the swell-shrink cycle shows up as tilted walls, cracked plaster, heaved slabs and broken canal linings, and shallow foundations bear the brunt of it because they sit right in the zone where seasonal moisture change is greatest. Deep foundations or complete soil replacement solve the problem but cost far more than a modest structure can justify, which is exactly why so much geotechnical research over the last few decades has gone into finding additives that can be mixed into the soil itself, cheaply, to bring the swelling and the strength problem under control at the same time.

B. Steel Slag

Every tonne of steel produced in a basic-oxygen or electric-arc furnace leaves behind a corresponding heap of slag, most of which still ends up in a dump yard rather than being put to use. Chemically it is not far from a slow-setting cement clinker, rich in calcium, iron, silica and magnesium oxides, and it is this composition that makes it interesting as a soil additive. Mixed into an expansive clay, the slag particles do two things at once - their angular, granular shape breaks up the continuous clay skeleton and adds internal friction, while the calcium they slowly release into the pore water encourages the clay platelets to flocculate rather than stay

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dispersed. The net effect reported in the literature is a drop in plasticity and swelling alongside a rise in density and bearing capacity. Using it this way also solves a disposal problem for the steel industry, so the appeal is as much environmental as it is technical.

C. Potassium Chloride

Where steel slag works mostly by bulking and mild cementation, potassium chloride attacks the swelling problem at its chemical root. Montmorillonite carries a net negative surface charge, which it balances by holding a cloud of hydrated cations - typically sodium and calcium - around each clay particle; this cloud, the so-called diffuse double layer, is what draws water in and forces the particles apart when the soil wets up. The potassium ion is unusual among common cations in that it loses most of its hydration shell and fits almost exactly into the hexagonal pocket on the clay's siloxane surface. Introduce a soluble potassium salt such as KCl into the pore fluid and the potassium ions displace the more loosely held sodium and calcium, collapsing the double layer and pulling the clay platelets closer together. The practical result is a soil that swells less, holds a lower liquid limit and plasticity index, and compacts to a higher density. Because it works quickly, costs little and is not classed as a hazardous chemical in the quantities used here, potassium chloride has performed better than several other chloride salts reported in earlier swelling-soil studies, and its effect is reported to be even more pronounced when it is combined with a slag or pozzolan that adds strength on top of the swell reduction.

II. OBJECTIVES OF THE PRESENT STUDY

1) Characterize the untreated expansive soil through its basic index and engineering properties before any additive is introduced.
2) Stabilize the soil using steel slag content dosed at 0,5,10,15 and 20% by dry weight of the soil and finding its optimum.
3) Stabilize the soil using a fixed optimum steel slag content combined with potassium chloride dosed at 0, 0.5, 1, 1.5 and 2% by dry weight.
4) Track how this steel slag-KCl combination changes the soil's free swell, consistency limits, compaction behaviour, soaked and unsoaked CBR, and triaxial shear strength.
5) Pin down the KCl dosage, at the fixed slag content, that gives the best combination of strength gain and swell reduction, so the treated soil can reasonably serve as a foundation bed.
6) Check how much of that strength gain depends on curing time by comparing CBR and triaxial results after 7 and 14 days.

III. LITERATURE REVIEW

Steel slag on its own has been tried at fairly high replacement levels. Zumrawi and Babikir [1] pushed it as high as 30% in an expansive clay and saw the liquid limit and plasticity index fall while maximum dry density rose and optimum moisture content dropped; unconfined compressive strength improved too, and the authors settled on a 10-15% range as the most cost-effective window rather than the full 30%.

A similar pattern turns up in Kabeta's work [2], where slag contents from 0 to 25% brought the free swell of an expansive soil down from about 105% to 58%, raised the maximum dry density from 1.50 to 1.69 g/cc, and very nearly doubled the soaked CBR - evidence that a single additive can tackle both the swelling and the bearing-capacity side of the problem at once.

Srinivas [3] tested slag replacements of 10, 20 and 30% and found that most of the benefit, in terms of plasticity, swelling, CBR and compaction, had already appeared by around 20%; pushing further to 30% added little, which matters when slag has to be trucked in and mixed on site. Potassium chloride by itself was the subject of Shukla, Parihar and Gupta's earlier paper [4], where dosages from 0 up to 9% steadily lowered the liquid limit and swelling potential of an expansive soil while raising its dry density, shrinkage limit and unconfined strength; they reported the best overall performance sitting around 8-9% KCl when it was used with no other additive.

The same group went on to test potassium chloride together with fine slag [5], using KCl between 0.5 and 1.5% alongside slag from 5 to 15%. Here the two additives clearly did different jobs - KCl drove most of the reduction in plasticity and free swell, while the slag was responsible for most of the gain in density and strength - and combining them gave more improvement than either one managed alone. That finding is essentially the starting point for the mix design adopted in the present study.

Working with an Iraqi expansive clay, Abdalqadir and Salih [6] confirmed the same broad trend with slag contents up to 20%: lower Atterberg limits and optimum moisture content, and higher dry density, unconfined strength and CBR, all moving together as slag content increased. Not every stabilization route relies on slag. Almajed, Dafalla and Shaker [7] paired calcium chloride with a small dose of cement and showed that a salt additive backed up by even a modest amount of binder controls swelling well while avoiding the long-term leaching concerns that come with using a chloride salt on its own - a reminder that salt-based treatments generally perform best when paired with a second material rather than used in isolation.

Reading these studies together, a fairly clear division of labour emerges: granular or pozzolanic by-products such as steel slag mainly add density and strength, while soluble salts such as potassium chloride mainly shut down the swelling mechanism at the clay-particle level. Since an expansive soil is troublesome on both counts, pairing the two kinds of additive - as done here with steel slag and potassium chloride - looks like a more complete fix than relying on either one by itself, and that reasoning is what motivated the laboratory programme described in the remainder of this paper.

IV. METHODOLOGY

A. Soil Collection

The soil sample is collected from the village somidevarapalem, mummidivaram manadal. The soil used in this study was dug by hand from an open field with a known history of black cotton soil, at a depth of roughly 0.5 to 1.0 m so as to stay below the surface layer of organic and root-affected material. Once back in the laboratory it was air-dried, broken down and passed through the IS sieves needed for classification and mix preparation, following the general procedure set out in IS: 2720.

B. Material

1)Steel Slag: The Steel Slag used in this investigation is a granular industrial by-product generated during the steel-making process. It was sourced from a steel manufacturing/casting unit at steel plant vizag and was used in its dry, pulverised state, after being passed through the appropriate IS sieve to achieve a uniform particle size.
2)Potassium Chloride: The Potassium Chloride employed in this study is a commercially procured, white crystalline salt that is readily soluble in water, of laboratory/analytical grade purity.

C. Mix Proportion

Different soil mixes were formulated using varying proportions of Steel Slag and Potassium Chloride to evaluate their combined stabilizing effect. In the first stage, Steel Slag was blended with the expansive soil at four dosage levels 5%, 10%, 15% and 20% by dry weight to identify the percentage that yields the best improvement in soil behaviour. Once this optimum Steel Slag content was established, Potassium Chloride was introduced into that particular soil–slag blend at 0.5%, 1%, 1.5% and 2% by dry weight of soil. This second stage allowed the mechanical stabilization achieved through Steel Slag to be assessed alongside the chemical stabilization provided by Potassium Chloride.

TABLE I
MIXED PROPORTIONS FOR TESTING EXPANSIVE SOIL

S. No.	Stabilizing Agent	Mix Proportion (%)
1	Steel slag	0, 5, 10, 15, 20
2	Potassium Chloride (KCl)	0, 0.5, 1, 1.5, 2

V. LABORATORY TESTING

Before any additive was introduced, the raw soil went through a full characterization programme: hydrometer analysis for grain size, differential free swell, natural moisture content, specific gravity, the three Atterberg limits, standard Proctor compaction, and soaked plus unsoaked CBR, each carried out broadly as described in the relevant part of IS: 2720. These results were then used to place the soil in the IS: 1498 classification system.
Each of the five mixes was subsequently tested for differential free swell, liquid limit, standard Proctor compaction, 7 and 14 days soaked CBR, and consolidated-undrained triaxial compression at both 7 and 14 days of curing, with three confining pressures used per triaxial specimen. Mixing followed the same routine every time - soil, slag and KCl were dry-blended first, water was added at the amount corresponding to that mix's optimum moisture content, and the wet mix was compacted into moulds, sealed in polythene, and left to cure at controlled humidity for the required period before testing.

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TABLE II
BASIC PROPERTIES OF THE UNTREATED EXPANSIVE SOIL

Properties	Symbol	Untreated BCS	Units
Clay content	-	84	%
Silt content	-	12	%
Sand content	-	4	%
Differential Free Swell	DFS	110	%
Natural Moisture Content	-	29	%
Specific Gravity	G	2.56	-
Liquid Limit	WL	83	%
Plastic Limit	WP	32	%
Shrinkage Limit	WS	13	%
Plasticity Index	IP	51	%
Soil Classification	-	CH	-
Maximum Dry Density	MDD	1.51	g/cc
Optimum Moisture Content	OMC	27	%
CBR (Unsoaked)	-	7.3	%
CBR (Soaked)	-	1.40	%
Cohesion	C	0.2	kg/cm^2
Angle of internal friction	ϕ	24^0	degree

VI. RESULTS AND DISCUSSION

A. Effect on Differential Free Swell

Untreated, this soil registered a differential free swell of 110% - high enough to rule it out as a foundation bed without some form of treatment. Simply adding 15% steel slag, with no salt at all, already brought that figure down to 90%, and from there each step up in KCl content pushed it lower still, ending at 40% for the 2% dosage. The mechanism behind this is the ion exchange described earlier: potassium ions from the salt take the place of the sodium and calcium ions clinging to the clay surface, and once that swap happens the diffuse double layer that used to draw water in simply isn't there anymore. Shukla et al. [4], [5] report the same falling trend in their KCl work, so this result lines up with what has already been observed elsewhere.

TABLE III
DIFFERENTIAL FREE SWELL OF TREATED MIXES

S. No.	Mix Proportion	DFS (%)
1	85% ES + 15% SS + 0% KCl	90
2	85% ES + 15% SS + 0.5% KCl	80
3	85% ES + 15% SS + 1% KCl	55
4	85% ES + 15% SS + 1.5% KCl	45
5	85% ES + 15% SS + 2% KCl	40

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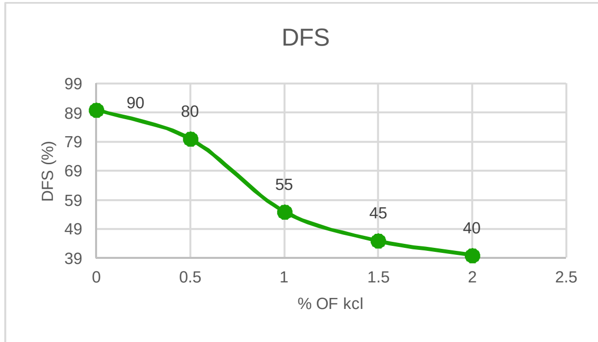


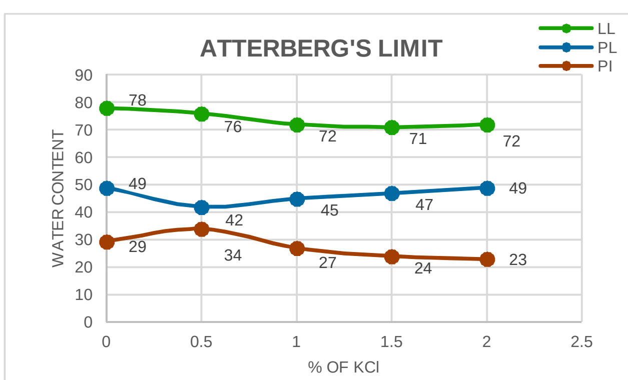
B. Effect on Atterberg limits

The liquid limit, plastic limit and plasticity index of the treated soil are summarized in Table III for the 85% ES + 15% Steel Slag mix at varying KCl content. The liquid limit declines for most of the range, from 77.93% at 0% KCl to a low of 71.26% at 1.5% KCl, before edging back up marginally to 72.17% at 2% KCl, a pattern consistent with the combined dilution effect of the slag and the double-layer contraction produced by the potassium cation. The plastic limit behaves quite differently: it first drops sharply from 48.55% to 42.38% between 0% and 0.5% KCl, and then rises steadily through the remaining dosages to reach 49.46% at 2% KCl, ending up close to its starting value. Because the plasticity index is the arithmetic difference between these two limits, this contrasting behaviour shapes the PI curve in an interesting way: PI actually increases from 29.38% to 33.69% as the first 0.5% KCl is added reflecting the sharper initial fall in PL relative to LL before decreasing consistently over the remaining dosages to its lowest value of 22.72% at 2% KCl. In other words, the early rise in plasticity index is essentially an artefact of how quickly the plastic limit initially drops, and once the potassium exchange process stabilizes, the reduction in liquid limit dominates and plasticity index falls to its best value at the highest KCl content tested.

TABLE IV

ATTERBERG LIMITS OF TREATED MIXES

S. No.	Mix Proportion	LIQUID LIMIT %	PLASTIC LIMIT %	PLASTICITY INDEX
1	85% ES + 15% SS + 0% KCl	78	49	29
2	85% ES + 15% SS + 0.5% KCl	76	42	34
3	85% ES + 15% SS + 1% KCl	72	45	27
4	85% ES + 15% SS + 1.5% KCl	71	47	24
5	85% ES + 15% SS + 2% KCl	72	49	23



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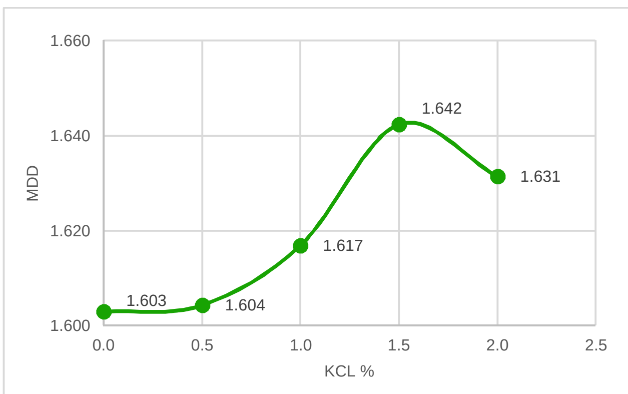
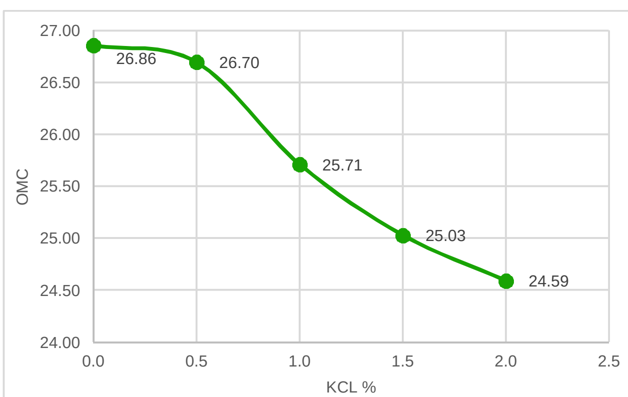
C. Effect on Compaction Characteristics

Compaction behaviour followed the same improving trend seen in the free swell and liquid limit results. For the raw untreated soil, the maximum dry density was 1.511 g/cc at an optimum moisture content of 26.6%. Simply adding 15% steel slag, with no potassium chloride yet (0% KCl), raised the dry density to 1.6030 g/cc and nudged the optimum moisture content up slightly to 26.857%. From that point, increasing KCl content pushed the dry density up further and pulled the moisture content steadily down: at 0.5% KCl the values were 1.6044 g/cc and 26.696%, at 1% KCl 1.6169 g/cc and 25.711%, and at 1.5% KCl the mix reached its peak dry density of 1.6424 g/cc at an optimum moisture content of 25.030%. Beyond this point the trend reversed mildly at 2% KCl the dry density eased back to 1.6315 g/cc while the moisture content continued falling to 24.592%. The density curve and the moisture curve therefore move as near mirror images of each other, both turning at the same 1.5% KCl dosage, which points to that mix achieving the most efficient particle packing: the potassium ions encourage the clay particles to flocculate rather than stay spread apart, and the finer slag grains settle into the remaining pore spaces, so the mix needs less water to reach its densest achievable state.

TABLE V
COMPACTION CHARACTERISTICS OF TREATED MIXES

S. No.	Mix Proportion	OMC (%)	MDD (gm/cc)
1	85% ES + 15% SS + 0% KCl	26.86	1.603
2	85% ES + 15% SS + 0.5% KCl	26.70	1.604
3	85% ES + 15% SS + 1% KCl	25.71	1.617
4	85% ES + 15% SS + 1.5% KCl	25.03	1.642
5	85% ES + 15% SS + 2% KCl	24.59	1.631





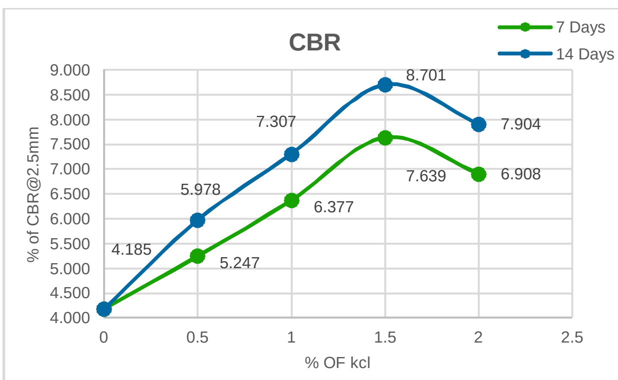
D. Effect on California Baring Ratio

This is where the practical payoff of the treatment shows up most clearly. The untreated soil's soaked CBR of just 1.395% - against an unsoaked value of 7.307% - is a textbook illustration of why expansive clay is such a poor subgrade: it loses most of its strength the moment it gets wet. Adding 15% slag alone lifted the unsoaked figure to 22.12% and the soaked figure to about 4.18%, and from there, seven days of curing with increasing KCl content pushed the soaked CBR up further still, peaking somewhere between 7.6% and 8.7% at 1.5% KCl - two independent trial batches gave 7.64% and 8.70% respectively - before dropping back a bit at 2% KCl. That the peak sits at 1.5%, not at the highest dosage tested, matches the same optimum already seen in the free swell, liquid limit and compaction results, and is a fairly strong indication that 1.5% KCl alongside 15% slag is close to the sweet spot for this particular soil.

TABLE VI

SOAKED CBR AT 2.5MM PENETRATION OF TREATED MIXES

S. No.	Mix Proportion	7 Days	14 Days
1	85% ES + 15% SS + 0% KCl	4.185	4.185
2	85% ES + 15% SS + 0.5% KCl	5.247	5.978
3	85% ES + 15% SS + 1% KCl	6.377	7.307
4	85% ES + 15% SS + 1.5% KCl	7.639	8.701
5	85% ES + 15% SS + 2% KCl	6.908	7.904



E. Effect on triaxial shear strength

The shear strength parameters obtained from the triaxial compression tests cohesion (c) and angle of internal friction (φ) bring out the same optimum already seen in the other results, but this time in the two parameters that actually govern shear failure. For the reference mix with no KCl (0% KCl), cohesion stayed flat at 1.4 kg/cm^2 and the friction angle at 11.53° regardless of curing period, which makes sense since there is no salt present to drive any time-dependent reaction. Once KCl was introduced, both parameters rose steadily with dosage: cohesion climbed from 1.42 kg/cm^2 at 0.5% KCl to a peak of 1.59 kg/cm^2 at 1.5% KCl after 7 days of curing, and the friction angle rose alongside it from 15.47° to 18.58° over the same range. After 14 days of curing, the same pattern repeated at consistently higher values cohesion peaked at 1.75 kg/cm^2 and the friction angle at 20.41°, both again at 1.5% KCl before both parameters eased back slightly at 2% KCl (cohesion falling to 1.66 kg/cm^2 and friction angle to 20.17° at 14 days). This is the fourth independent test in this study after free swell, CBR and compaction to show 1.5% KCl as the dosage giving the best shear strength response. The consistent gain between 7 and 14 days across every mix also confirms that the improvement in shear strength is not just an immediate physical effect of mixing but continues to develop with curing time, most likely as the ion-exchange and mild cementing reactions between the clay, slag and potassium chloride keep progressing after compaction.

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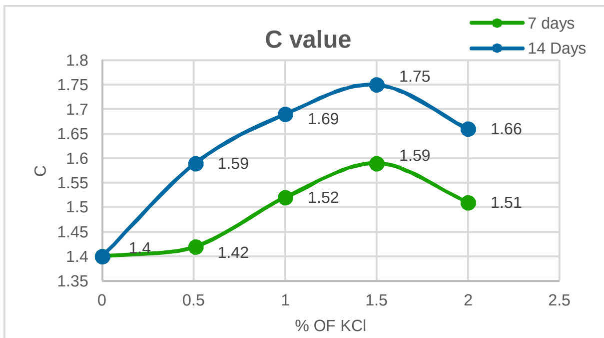
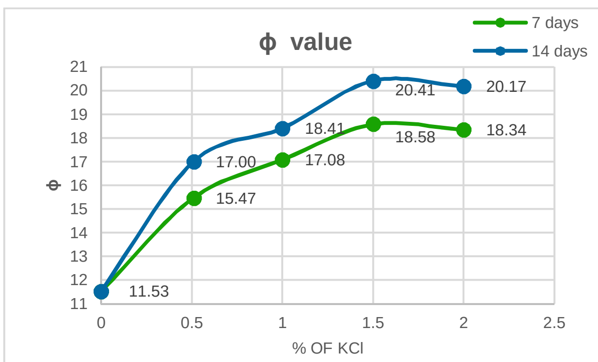
TABLE VII
C AND Φ VALUES FROM TRIAXIAL COMPRESSION TESTS

S. No.	Mix Proportion	7 Days		14 Days	
		C	ϕ	C	ϕ
1	85% ES + 15% SS + 0% KCl	1.4	$11^0$53’	1.4	$11^0$53’
2	85% ES + 15% SS + 0.5% KCl	1.42	$15^0$47’	1.59	$17^0$00’
3	85% ES + 15% SS + 1% KCl	1.52	$17^0$08’	1.69	$18^0$41’
4	85% ES + 15% SS + 1.5% KCl	1.59	$18^0$58’	1.75	$20^0$41’
5	85% ES + 15% SS + 2% KCl	1.51	$18^0$34’	1.66	$20^0$17’





VII. DISCUSSION SUMMARY

Looked at side by side, the five sets of results tell essentially the same story from five different angles. Free swell, liquid limit, plasticity index, compaction density, soaked CBR and the triaxial shear parameters all trace out the same shape as KCl content increases at the fixed 15% steel slag dosage: steady improvement through 0.5%, 1% and 1.5% KCl, followed by a mild reversal at 2%. That every single test despite measuring quite different physical behaviour turns over at the same 1.5% dosage is not something one would expect from chance alone, and it points fairly convincingly to a real physico-chemical ceiling being reached at that point. The explanation offered for each individual result earlier fits together into one coherent picture: potassium ions progressively displace the sodium and calcium clinging to the clay surface, collapsing the diffuse double layer and letting the flocculated clay particles pack more tightly around the angular slag grains. Up to about 1.5% KCl there is still enough exchangeable surface area on the clay to keep absorbing potassium and keep gaining benefit from it; beyond that point the exchange sites are essentially saturated, so any additional salt simply sits in the pore water as a free electrolyte rather than doing further structural work, which is consistent with the small give-back seen in every parameter at 2%.

It is also worth noting how much of the improvement steel slag was already responsible for on its own. Before any KCl was added, the slag-only mix had already cut the free swell from 110% to 90%, raised the soaked CBR from 1.395% to about 4.2%, and lifted cohesion and friction angle well above what the untreated soil offered. Potassium chloride then built on that base rather than working in isolation, which matches the division of labour reported by Shukla et al. [5] for their fine-slag-KCl combination: the salt mainly attacks plasticity and swelling, while the slag mainly supplies density and strength, and the two together do considerably more than either manages alone. The consistent gap between the 7-day and 14-day CBR and triaxial results across every mix is a further piece of evidence for this chemical mechanism, since a purely granular effect from the slag would not be expected to keep improving with time the way an ongoing ion-exchange and mild cementation reaction would.

From a practical standpoint, the numbers at the 1.5% KCl dosage are what matter most. A soaked CBR of 8.7% after 14 days of curing, up from a starting point of 1.395%, moves this soil from a category that would normally be rejected outright as a subgrade into a range that is workable for lightly trafficked pavements and ordinary foundation beds, provided the usual precautions adequate cover, drainage and compaction control are still followed. The accompanying fall in free swell to 45% and in plasticity index to about 24% further reduces the risk of the seasonal heave and shrinkage that make black cotton soil such a difficult founding material in the first place. Taken as a package, 15% steel slag combined with 1.5% potassium chloride looks like a genuinely balanced treatment rather than one that trades one problem for another, and it achieves this using a waste product and a comparatively small quantity of an inexpensive salt.

VIII. CONCLUSION

1) The laboratory programme confirms that this black cotton soil, troublesome as it was in its raw state, responds well to a combined steel slag–potassium chloride treatment, and the results support the following conclusions.
2) The untreated soil classified as CH, with a differential free swell of 110%, a liquid limit above 83%, a plasticity index above 51%, and a soaked CBR of only 1.395%, confirming it as unsuitable for direct use as a foundation bed without treatment.
3) Steel slag alone, fixed at 15% of the dry soil weight, produced a worthwhile improvement even before any potassium chloride was added, reducing the free swell to 90% and raising the soaked CBR to roughly 4.2%, showing that the granular bulking and mild cementing action of the slag has real value on its own.
4) Adding potassium chloride to this slag-treated soil improved every property tracked in the study, consistently up to a dosage of 1.5%, beyond which each parameter eased back slightly at 2% KCl. This turning point was observed independently in the free swell, Atterberg limits, compaction, CBR and triaxial results, which is strong evidence that 1.5% KCl represents a genuine optimum for this soil-slag combination rather than an artefact of any single test.
5) At the identified optimum of 15% steel slag with 1.5% potassium chloride, the differential free swell fell from 110% to 45% (a reduction of just over 59%); the liquid limit dropped from about 83.3% to 71.3%; and the plasticity index came down from 51.2% to roughly 24.1%, cutting the swelling potential of the soil by more than half.
6) Compaction characteristics improved alongside the plasticity results, with the maximum dry density rising from 1.511 g/cc to 1.642 g/cc while the optimum moisture content needed to reach it fell from 26.6% to 25.0%, indicating a more efficient, better-packed soil structure at the optimum dosage.
7) The soaked CBR arguably the single most important parameter for foundation and pavement design rose from 1.395% in the untreated soil to 8.701% after 14 days of curing at the optimum mix, an improvement of more than six times, taking the soil from a practically unusable subgrade to one that meets reasonable strength expectations for light structures and pavements.
8) Shear strength parameters from the triaxial tests followed the same trend: cohesion and the angle of internal friction both rose steadily with KCl content up to 1.5%, reaching 1.75 kg/cm² and 20041' respectively after 14 days, before easing back slightly at 2% KCl, mirroring the pattern seen in every other test.
9) The gap between the 7-day and 14-day CBR and triaxial results at every KCl dosage shows that the strength gain is not just an immediate mechanical effect of mixing but continues to develop with curing time, most likely reflecting ongoing ion-exchange and mild cementation reactions between the clay, the slag and the potassium chloride.

Overall, the combination of 15% steel slag and 1.5% potassium chloride offers a practical, economical and comparatively fast-acting means of converting an otherwise problematic expansive soil into a stable foundation bed, while also making productive use of an industrial by-product that would otherwise go to waste.

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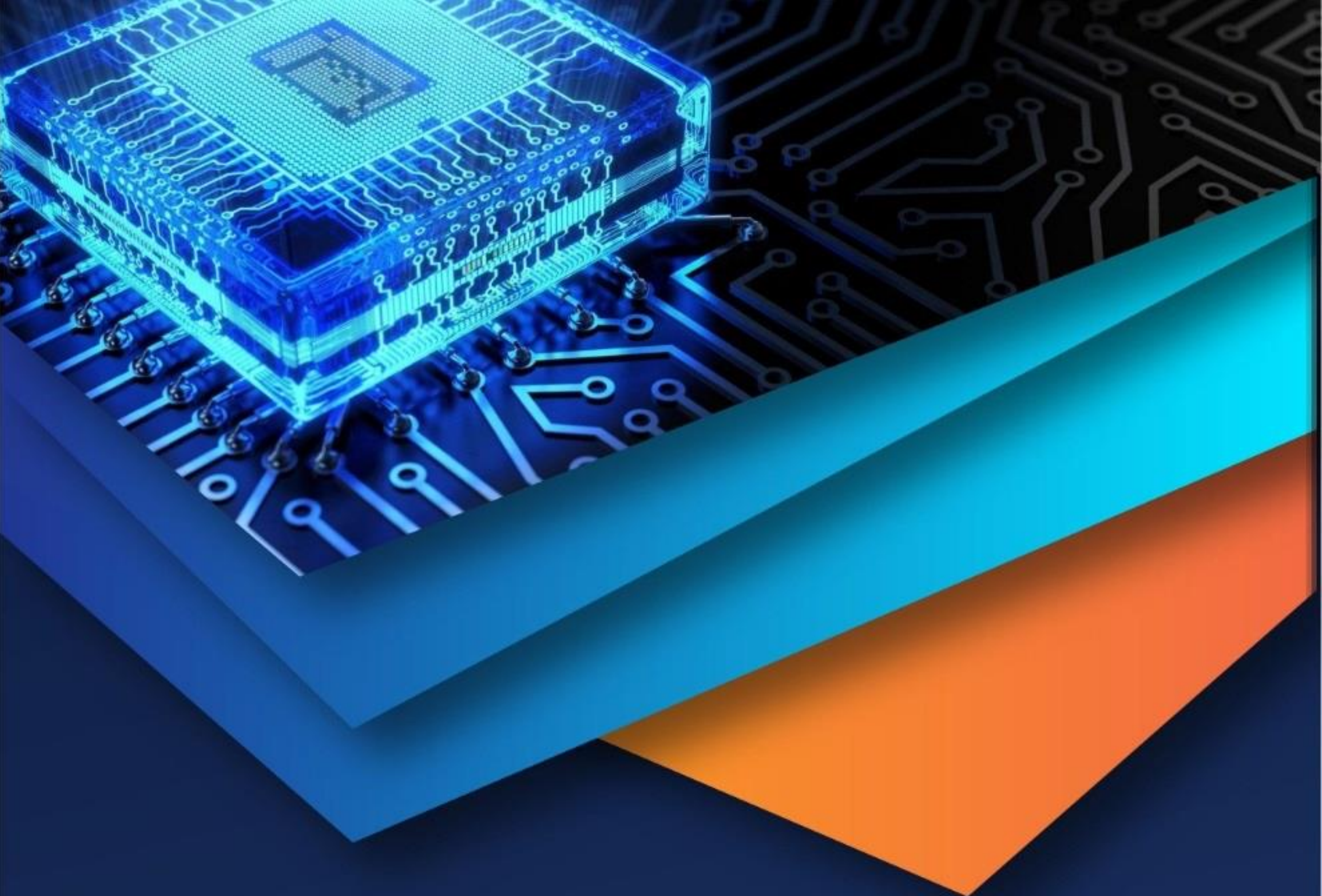

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