The general requirement, in these kinds of game, is of a pitch which would batsmen friendly. Ideally it should produce a condition equivalent to that on the second or third day of a five-day game. This suggests that water should be withheld from 1-2 days ahead than done so for a five day game to allow proper drying.

2. Materials and Methods

For the purpose of in depth study the contents have been taken from the relevant books, research articles, journals, and websites. The method is analytical and descriptive in which both the primary and secondary sources of information have been taken.

3. Results and Discussions

All the three formats of cricket, mentioned above, are played on the same pitch soil but the results may differ. It is not only the good quality clay soil with high percentage of clay contents but the type of clay minerals (either 1:1 or 2: 1 Kaolinite, Illite, Vermiculite or Smectite) is much important. Even with less percentage of clay % (as in Australia), like the Smectite type of clay, often produces a good bouncy and fast pitch as compared to pitches having non- expanding or less expanding lattice structure like the Illite or Kaolinite type of clay minerals. High level of clay % with smectite or vermiculite type of clay minerals is the **DNA** of any cricket pitch which defines its nature and behavior.

Rolling the above mentioned pitch soil with good and uniform grass binding at the calculated **Optimum Moisture Content** with different planned schedules has been reported to produce entirely magical results. Every pitch soil can be compacted and consolidated only at different Optimum Moisture Content which has to be examined properly by adopting scientific methods (CBR–California Bearing Ratio or Modified Proctor Test).

Maintaining uniform and deep rooted grass growth is one of the major reasons of having a fast and bouncy wicket as it helps in deep drying by the help of transpiration and by providing a firm structure to the pitch soil. It acts as a skeleton of a pitch which provides a firm shape and structure to it. A**s** in human beings skeleton along with the muscles provides a definite shape to the body the same analog is applicable to the pitches also in which the pitch soil acts as a muscles and the deep rooted grass acts as skeleton, both collectively providing a definite and firm shape and structure to the pitch profile.

The above mentioned desired ideal characteristics in all different available forms of cricket can only be achieved by;

1. Having a pitch soil with high clay % preferably the Smectite or Vermiculite. Kaolinite is not, at all, desirable.
2. Achieving the maximum bulk density (compaction and consolidation) of the pitch by rolling with proper roller weight and schedule at the calculated Optimum Moisture Content.
3. Having deep rooted uniform grass cover throughout the pitch profile.

Above three conditions could be brought about by adopting the scientific ways based on the recent research and developments which can bring entirely different results even in the same pitch with same microclimate (Temperature, Relative Humidity, Evapo-transpiration Rate, Wind speed and available suspended air moisture in the form of Fog, Mist or Dew) as well as macro-climatic conditions. The conventional or traditional mind-set and style of making pitches without having scientific and logical reasons should be changed **as there is always a science behind the art of pitch making**. Nearly, total cost of laying a new multiple pitch and outfield (drainage system and modern irrigation facilities) with scientifically approved layers comes out to be only **1-2 %** of the total project cost.

Newly laid pitches and outfield have nearly 10-15 years of economic life during which they provide results of International standards. Its life is restricted due to gradual accumulation of the dead organic matter and pitch grasses (converted to humus) thereby slowly reducing the clay % present in the pitch profile. Further, different layers occur in the pitch profile due to use of different pitch soil as used in the initial stages and also due to faulty rolling schedules. Heavy salt accumulation is there in the pitch layer which affects the pH level thereby affecting the nature and behavior of the pitches. Secondly, the use of clay soil for pitch laying and sandy loam/sand for laying the drainage layer make the outfield layer scarce, expensive requiring mineral resource treatment as done in most of the states in India. Hence, these materials should be used very judiciously according to the specific and prescribed requirements of different layers.

Undesirably multiple layering of surface (not more than 300 mm) and sub surface layer (nearly 200-250 mm only) would only add to increased project cost. Re-laying or renovating the existing pitch and outfield in a non scientific manner requiring additional maintenance will only produce a different undesirable behavior and will call for additional recurring cost to the project.

In addition to the above mentioned ideal conditions, in different levels of cricket, the cricket pitch soil should have the following important characteristics as well;

1) Have a Plasticity which allows remolding and compaction by rolling, thus giving a smooth surface.
2) Have a deeply dried hard surface so that the elasticity of the ball is manifested and preferably allows turn of the ball at some stage (a hard clay surface is itself elastic). In other words, an elastic surface will provide good bounce for the fast bowlers and turn for the spinners.
3) Have soil cohesion that provides vertical stability preventing differential change in elevation of parts of the surface, lifting out of crumbling or powdering. There should not be any break at depths causing plating, or the surface to flake.
4) Have an ability to recover from the compaction, brought about during the preparation, so that the soil structure and the Bermuda grass can regenerate after the play. The soil must be cracking clay. When the soil cracks it de compacts itself and allows air and water to enter into the

root zone of the grass, thus rejuvenating both the soil and the grass.

5) Should neither crack excessively (crumbling) nor have excessively wide cracks.
6) Should have a sufficiently high permeability when wet, to ensure reasonable rates of water movement and leaching of salts. Different clays have different rates of hydraulic conductivity (rate at which water moves through the soil). A suitable pitch soil should have a reasonable hydraulic conductivity so that the water can move slowly right through the profile along with the movement of salts with it.
7) Should have a means of removal of excess water so that aeration occurs, as well as the removal of salts through the drainage layer lying beneath. There needs to be a permeable layer directly under the clay soil to allow excess water and salts to drain out of the wicket soil into it.
8) Should have a completely uniform grass cover, preferably with Couch grass prior to the final preparation, with uniformity of root penetration to an appreciable depth (at least 100 mm**)**. This is essential to give uniform moisture levels and rates of drying of the surface and top 100 mm.
9) Should be rich in nutrients, available essential minerals and humus basically in colloidal state.

To summarize, the above mentioned ideal standards can only be found in the pitch soil which has plasticity for rolling, a smooth and hard surface after rolling, regulated cracks, has a good drainage rate (hydraulic conductivity), and recovers from the compaction of preparation to allow good grass growth.

The above mentioned ideal conditions desired by the ICC or the BCCI at the international level can only be achieved by following scientific ways of selection of good pitch soil by analyzing its physical, chemical, mineralogical and engineering properties over the time taking traditional style of making pitches in India which is generally based on permutations and combinations and the skills transformed from one generation of grounds man to another. Based on the scientific research and developments the desirable Physical, Chemical, Mechanical and Mineralogical examinations to get the above mentioned results are as follows;

A. Physical analysis - Particle size analysis for soil texture, Crushing Strength, Cracking pattern, linear shrinkage, Emersion and Dispersion Index.
B. Chemical analysis – Chloride, Sodium , Potassium, Calcium, Magnesium and its ratio, Ph in water and cacl2 , Cation Exchange Capacity, EC total salts , ESP- Exchangeable Sodium percentage , % Organic Matter in oven dried soils, CaCo3 – Calcium carbonate (The difference Between the Sodium, Potassium, Calcium, Magnesium and the CEC gives the Hydrogen ion concentration).
C. Mineralogical analysis - X- RAY DIFFRACTION method to determine the Structure and type Of Clay minerals either Kaolinite, Illite, Smectite or Vermiculite having 1:1 or 2:1 structure.
D. Engineering – Atterberg limits, Soil strength, compatibility, penetrability, through Procter or modified Procter test, Shear strength (traffic- ability) or CBR – California Bearing Ratio.

Table 1: Standard ranges of different parameters and their relevance's

	Properties	*Desirable Values*	*Relevance*
A	**Physical properties**		
	Soil Texture		
	Clay (< .002 mm)	50- 70%	Have high plasticity, elasticity, high water holding capacity, high compaction level, de-compacts and grass growth and post match recovery is fast.
	Silt (.002- .02 mm)	5-20 %	
	Sand- Fine (.02- .25mm)	10-20 %	
	Medium (.25- 1.00 mm)	0-10 %	
	Coarse (1. -2.0 mm)	1%	
	Crushing Strength	0.8- 1.6 - MPA	to analyze the soil cohesion or strength to
			With stand the ball impact.
	Cracking Pattern	2-5 pcs desirable	the width and number of cracks is essential
		6-10pcs acceptable	for good grass growth and after match
		> 11 Not acceptable	recovery and reconsolidation.
	Linear Shrinkage	8- 15 %	to analyze physically about the nature and
	(COLE- Coefficient -		type of clay having shrinking and swelling
	Of Linear Shrinkage)		Capacities.
	Emersion Test	Value 6 desirable	to analyze physically about the dispersibility
			of the pitch soil.
	Dispersion Index	Value 8 desirable	
	Free Swell	< 50 %	

B	**Chemical Analysis**		
	Sodium level	< 5 me %	High Na level reduces the Hydraulic Conductivity leading to more dispersion which causes pores to be blocked by migrating particles.
	EC Na ,Ca+ Mg+ K+ Ca+ / Mg+ Ratio		The soluble salts should be as low as possible, as excessive salts may possibly cause crumbling of soil (Harris 1961
	ESP	< 3-5	Hydraulic conductivity decreases with increase in ESP.
	PH	6-7 in water and 5-6 in CaCl2	regulates the available nutrients and micro- nutrients in the soil also affects the swelling capacity of clay minerals.
		< 0.15	above causes the soil crumbling.
	CaCo3 or MgCo3	< 1%	above causes the soil mulching.
	Organic Matter	< 5 %	
D	**Engineering Properties**		
	Atterberg Limit		For Soil classification based on Liquid, Plastic, Shrinkage limit and Plasticity Index.
	Clegg Hammer Test		to test the compaction level or surface hardness
		(207-424) g	Average readings
		< 200 g	Slow Pitch.
		(200-350)	Medium Fast Pitch.
		> 350 g	Fast Pitch.
E	**Mineralogical Properties**		
	(through X-Ray Diffraction)		To analyze the structure and clay minerals type either Kaolinite, Illite, with 1:1 or 2:1 structure.Smectite or Vermiculite

Table 2: Information of some important Indian Cricket pitches.

	Name of the Stadium	Test	ODI	T 20	First match	Last match
1	Roop Singh Stadium, Gwalior, Madhya Pradesh	0	12	0	22-Jan-88	24-Feb-10
2	Rajiv Gandhi International Cricket Stadium, Hyderabad, Andhra Pradesh	3	4	0	16-Nov-05	02-Mar-13
3	PCA Stadium, Mohali, Punjab	11	21	1	22-Nov-93	14-Mar-13
4	Nehru Stadium, Indore, Madhya Pradesh	0	9	0	01-Dec-83	31-Mar-01
5	Nehru Stadium, Guwahati, Assam	0	16	0	17-Dec-83	28-Nov-10
6	Moin-ul-Haq Stadium, Patna, Bihar	0	2	0	15-Nov-93	27-Feb-96
7	M. Chinnaswamy Stadium, Bangalore, Karnataka	20	23	1	22-Nov-74	25-Dec-12
8	M. A. Chidambaram Stadium, Chennai, Tamil Nadu	31	20	1	10-Feb-34	22-Feb-13
9	Lal Bahadur Shastri Stadium ,Hyderabad, Andhra Pradesh	3	14	0	19-Nov-55	15-Nov-03
10	Keenan Stadium, Jamshedpur, Jharkhand	0	10	0	07-Dec-83	12-Apr-06
11	JSCA International Cricket Stadium Ranchi, Jharkhand,	0	2	6	19-Jan-13	23-Oct-13
12	Jawaharlal Nehru Stadium, Kochi, Kerala	0	8	0	01-Apr-98	15-Jan-13
13	Indira Priyadarshini Stadium, Visakhapatnam, Andhra Pradesh	0	5	0	10-Dec-88	03-Apr-01
14	HPCA Stadium, Dharamsala, Himachal Pradesh	0	1	0	27-Jan-13	27-Jan-13
15	Holkar Cricket Stadium, Indore, Madhya Pradesh	0	3	0	15-Apr-06	08-Dec-11
16	Green Park Stadium, Kanpur, Uttar Pradesh	21	12	0	12-Jan-52	27-Nov-13
17	Feroz Shah Kotla, Delhi	32	23	0	10-Nov-48	22-Mar-13
18	Eden Garden, Kolkata, West Bengal	38	27	1	05-Jan-34	03-Jan-13
19	DY Patil Stadium, Navi Mumbai, Maharashtra	0	1	0	11-Nov-09	11-Nov-09
20	Brabourne Stadium, Mumbai, Maharashtra	18	8	1	09-Dec-48	12-Dec-09
21	Barabati Stadium	2	17	0	27-Jan-82	29-Nov-11

Data Source – Wiki-Pedia, The Free Encyclopedia.

Some of the above mentioned important Indian cricket stadiums hosting National and International tournaments since the Independence era are laid on traditional or conventional styles with number of multiple layers (even 5 to 7) and without or with very poor drainage systems. Recent research and developments prove that 2 or 3 layer wickets are economical and prudent to get the best pitches. Rollers used for compaction has its maximum vertical density only to the depth of 4 inches only. Nearly, only 8 inches of sandy loam and river washed sand (4 inches each) are required to act as a drainage layer only. Thick layer of clay pitch soils more than 300 mm only creates a pitch layering and acts as a source of perched water table only. Excess moisture is retained in this thick layer of pitch soil and affects the nature and behavior of playing surface. Most of the pitches will have to be renovated according to the latest prescribed scientific norms of pitch layering .Even the recently developed stadiums in the last five years have laid down their pitches without examining the mineralogical composition of pitch soils without which the above mentioned objectives of having a good pitch as found in the other playing continents cannot be achieved. The above mentioned ideal conditions desired by the ICC or the BCCI at the international level can only be achieved by having a scientific ways of selection of good pitch soil by analyzing its physical, chemical, mineralogical and engineering properties over the long ways of traditional style of making pitches in India which is generally based on permutations

and combinations and the skills transformed from one generation of grounds man to another.

4. Review of literature

Ekwue, E. I., Lall ,D. Z. and Stone , R. J., - Engineering Properties of Major Soils Used in Cricket Pitches in Trinidad , West Indies Journal of Engineering Volume 28, No.2, (January 2006) Technical Paper.

The conclusions and inference drawn from the above mentioned article are as follows-

"Ground curators always prepare cricket pitches by feel. Curators depend on their senses to determine.

When a pitch has sufficient water and has been rolled enough to achieve a good result, which includes a durable pitch that allows for good bounce and pace of the ball. Scientific measurements of moisture content, compaction at OMC, infiltration rates and other parameters are not used in preparation of cricket pitches. The need for the detailed study of soil properties used in cricket pitches is very important in order to help in advising curators in their preparation and maintenance of pitches." Apart from physical and chemical properties, soil engineering properties like the compactibility and compressibility at OMC , shear strength and penetration resistance also influences the performance of cricket pitches. The ideal cricket pitch should have- 50-60 % clay , less than 10% coarse sand, less than5 % calcium carbonate and Sodium levels , a linear shrinkage of .08 -.015 and less than 5% organic matter. Presently, the game demands a fair, precise, durable and sometimes predictable pitch in order to achieve a Successful both batsman and bowlers. The above mentioned ideal conditions can only be achieved by performing Mineralogical test (through XRD) to find out the type of clay minerals either highly swelling and shrinking Smectite, Vermiculite or limited or non expanding Kaolinite or Illite lattice structure. Clay mineralogy is the DNA or Genes of any pitch soil which provides the intrinsic template to have all the desired physical, chemical or engineering properties for a good pitch.

Research need or future scope of this study

In India, traditional style of pitch making with least concentration on pitch soil sampling and its analysis on physical, chemical, mineralogical and engineering properties before its use in pitch preparation is the general trend. It was done merely on the basis of permutation and combination and skill developed from generations to generations. Even in the process of pitch soil type selection and its layering concepts (either 3, 4, or 5 layered wickets) , deep rooted grass selection and its uniform growth , rolling concepts and its schedule at the optimum moisture content for maximum compaction are directly affected by the type and nature of soil used for preparing a pitch. Countries like South Africa, England, Australia and New Zealand are having bouncy and fast pitches only as a coordinated effort by the localized cricket associations, Engineering and Agricultural colleges. Their valuable research and development based on the experience and skills of the grounds man and curators either on pitch soil selection, their layering , grass variety selection and maintenance , rolling techniques and patterns , maximum compaction level at the optimum moisture content etc. can only produce fast and bouncy pitches in India at the international arena. In India scientific research and development with the involvement of centralized Agricultural and Engineering universities along with the BCCI and the local state units associations working on individual localized and acclimatizes soil and weather conditions can only bring the face of the dead flat and slow wickets. The broad gap in between the nature and character of Indian pitches with that available in the South Africa, England, Australia and New zealand can only be changed by the coordinated efforts of the above mentioned institutions only. The old traditional, unscientific style of pitch preparation and maintenance process has to be changed which will change the total nature and character of the Indian pitches. As through the process of evolution human kind , the Genes are the basic block which builds the nature and character of humans beings. Soil type and its basic minerals (either illite, kaolinite, montmorillonite or smectite) are the genes of any pitch soils which defines and governs the basic nature and behavior of any pitch. This can only be achieved by having the detailed physical, chemical, mineralogical and engineering property analysis of pitch soil before its final selection and use.

Hypotheses

1) It is said that a good quality of international cricket can only be played only on standardized good quality pith only. The above mentioned ideal conditions desired by the ICC or the BCCI at the international level can only be achieved by having a economic and scientific ways of selection of good pitch soil by analyzing its physical, chemical, mineralogical and engineering properties over the long ways of traditional style of making pitches in India which is generally based on permutations and combinations, trial and error basis and the skills transformed from one generation of grounds man to another.
2) As through the process of evolution human kind , the Genes / the DNA are the basic building block which builds the nature and character of humans beings. Soil type and its basic minerals (either illite, kaolinite, montmorillonite or smectite) are the genes of any pitch soils which defines and governs the economic viability and basic nature and behavior of any pitch. This can only be achieved by having the detailed physical, chemical, mineralogical and engineering property analysis of pitch soil before its final selection and use commercially.

5. Conclusions

Previously the above Physical and Chemical analysis of pitch soils were only considered as a litmus test for preliminary acceptance or rejection of the pitch soil samples. Soils with high clay contents with acceptable desired physical and chemical parameters were generally finally accepted as laying down the pitch. But the recent studies suggest that the mineral type present in the clay soil is much more vital than the high percentage of clay content. Pitch soils with very high clay content but with none or less

expanding lattice structures such as Illitte or Kaolinite clay minerals are undesirable as a pitch soil.
Pitch soils even with low clay percentage but having Smectite or Vermiculite type of clay minerals are mostly desired as a pitch soil.

Smectite or Vermiculite clays are a group of clay minerals that are able to expand and contract in one dimension as they absorb water or dry like a stack of papers that can become taller. The structural layer of these type of clays have a small negative charge therefore, attracts water molecules or other polar into the interlayer area , causing expansion. These water molecules are generally aligned around positively charged ions or cations such as Na+ or Ca+2 (interlayer cations) and next to the layer.

The amount of swelling or shrinking is related to the type of interlayer cations present in the lattice structures. Sodium rich smectite clays expand more than those containing calcium.

Therefore, in modern era of pitch soil selection and analysis of clay mineralogy type Illite, Kaolinite, Vermiculite or Smectite will be considered as a basic preliminary test so as to accept or reject the soil samples to be finally used as a pitch soil.

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