Paper No. 333

The Planning and Design of Modern Stadiums

By

*MUHAMMAD ASHRAF

B.Sc. (Eng) Honours London., A.M.I Strut. E. London. P.S.E. I.

I. GENERAL.

1. Introduction.

Pakistan is one of those fortunate countries which have rich natural reserve of sports talents. Since Independence, Pakistan's magnificant victories in various games in international meets have placed her on the sports map of the World. Her victories in cricket, abroad and at home, need no mention and the thrill packed matches attracted unmanageable crowds. During the last Olympics, Pakistan displayed an outstanding exhibition in the sport of hockey and impressed the World with speed and clever position play. Our athletes have been fully established in field and track events.

Due to these victories and achievements our Nation has become sports intoxicated. There is an over whelming demand for further development and improvement in the existing performances. This can only be accomplished by adequate regular training, tournaments and competitions which are necessary to test talents and to give poise and confidence. The very atmosphere of a tournaments, tense and taxing, is apt to bring the best out of a sportsman and it is in competition that a great sportsman really discovers himself. A good competition acts as a powerful spur to sport, whips up interest among the people and draws large crowds to the contest.

Regular tournaments and international meets, so necessary for raising the standard of sports and national prestige, can only be organised if adequate sports grounds and stadiums are available within the country. Throughout the country, improvised sports grounds and viewing stands are appearing every year. Small stadiums at Bhawalpur, Montgomery, Peshawar and at various other places have been built. The Army is developing stadiums in important cantonements. The Municipalities of Khanpur, Hyderabad, Lyallpur and Rawalpindi etc., have ambitious schemes. An international crickets stadium at Karachi has become focal point of activity and large stadiums are under construction at Dacca

*Executive Engineer Stadium Construction Division, P.W.D. (Buildings andRoads)., Lahore.

and Lahore. The number of grand stands and stadiums is certain to increase substantially in the years ahead.

The planning and design of stadiums is a highly specialized subject with a limited scope on which practically no standard comprehensive text is available. The small stadiums being developed by the local bodies are the seeds for future large ones. Their smallness does not excuse planning which ignores efficient and economical maintenance and operation, wastes space, slights spectators convenience and enjoyment, defeats maximum participants performances, abuses public relations and disregards future growth and demands. In one or two cases, tragic errors have been committed due to ignorance, false economy or a tendency to immitate. In our country, the position of architects is not likely to improve in the near future and as such the problem remains the complete concern of engineers. The Author hopes that greater understanding and attention to planning, designing and detailing will eliminate errors and will add greatly to the usefulness of the stadiums without effecting the initial cost.

2. Definition.

The definition of the word stadium is an evolution from the Greek. It was originally applied to a measure of distance being equal to about 606 ft, and then became transferred to indicate the race. Later the term was used to designate the race course on which such a distance was laid out. The curved embankments around the Greek race courses were flanked with terraced seats for spectators and the name stadium was applied to the complete layout. In modern usage the stadium is one of the several words applied to a large construction, covered or uncovered, which combines space for games and seats for spectators.

3. History

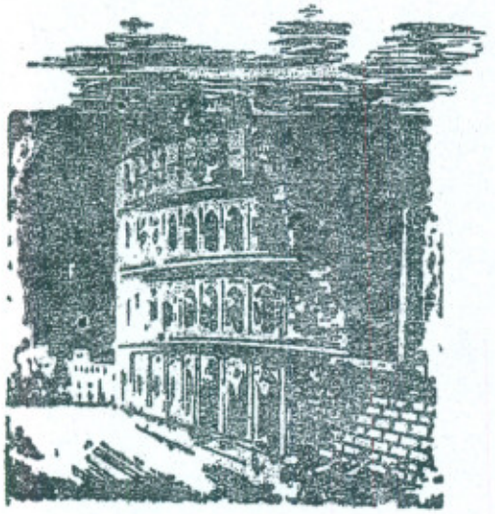
The Greeks built one of the first stadiums at Olympia for the famous games of the day. At a later stage the Romans built several types of structures for similar purpose and the Colleseum is very popular. The ravages of time and disuse have largely destroyed it but its elliptical shape, parabolic rise of successive tiers for sight clearance, exit and entrance system, and other principals of design and architectural treatment have been adopted in present practice. In general outline, it still remains one of the most magnificient stadium ruins in the world.

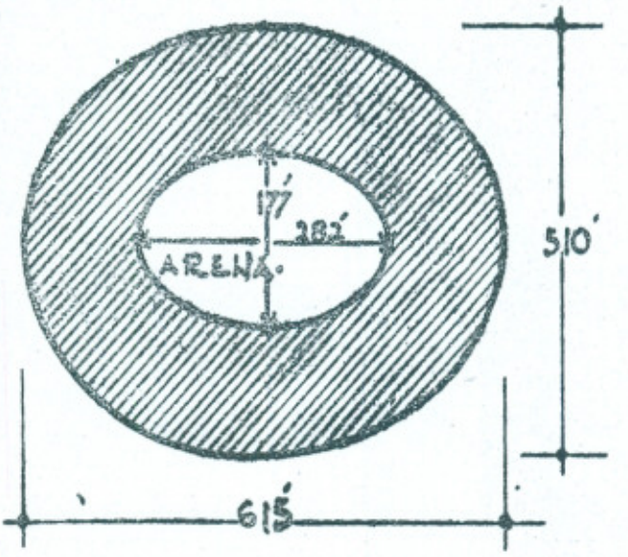
After the fall of Roman Empire sports played a minor role in mens lives and for nearly twenty centuries the stadium building was a lost art. During the 19th century physical exercises were revived and due to the efforts of a Frenchman, organised athletics became a regular international feature. Reconstruction of stadium at Athens in 1896 revived the building of large permanent stadiums.

FIG. 1.

COLLESEUM - ROME.

COMPLETED 217 A.D.
CAPACITY - SEATING. 45000.
" - STANDING. 5000.
NO OF EXITS & ENTRANCES. 76.
CIRCUMFERENCE 1722 ft.
GROSS AREA PER SEAT 4.55 SQ. ft.





Great Era of modern stadium construction started early in 20th century. Since then stadia of various shapes and seating capacities have been constructed practically in every country. America and U.S.S.R have throbbing net works of them. Some are designed for one sport only while others, along with some games, embrace field and track events. It could be safely said that the number of stadia in any country is an index to the physical and mental development of its people and the economic condition of the country as a whole.

4. Scope of Paper.

Effective planning and design utilizes fully the possibilities afforded by the site for the attainment of the purposes desired. The creation of

an effective and attractive plan of a stadium confronts the designer with several major problems, namely, accessibility, integration and effective use of the proposed site, flexibility, validity and multiple use of the proposed developments, convenience and safety of public and participants, economy in construction and maintenance, ease of administration, supervision and operation, and conformity to the principals of good architecture etcetra. No standard design or pattern can be applied for each project calls for resourcefullness, skill and understanding on the part of the designer. However, intimate knowledge of certain basic facts, principals and procedures, understanding of sports needs and interests, availability of data about playing fields, their measurements, orientation and specifications etcatra are very essential. Then the solution lies on the ability of the designer to arrange these factors in most appropriate and economical way. This paper describes some of the most important basic factors.

All the suggested principals of design and functional planning apply to large as well as small stadiums.

II. SITE SELECTION

The location of the stadium must be convenient and readily accessible from the startagic points and transport stations of the city. Comparatively level and well drained areas free from strong wind currents and with adequate water supply are most suited and economical. Some times uneven and low lands, conveniently situated and available at cheaper rates, can be economically developed to create æsthetic value and sports assests with some disadvantages in the stagnation of air which retards drying of fields and occasionally works a hardship on the players. Attractive surroundings have much greater influence and appeal. Ugly and drab environments must be avoided. The site should also be away from air fields, fire stations, hospitals, factories, rail road or other hazardous factors. Due regard should be given to the proximity of other buildings and disturbing factors of odour, noise, dust and smoke which might handicap the stadium programmes. Location in the heart of a residental area should also be avoided, if possible, because the noise and congestion resulting from the large crowds attracted to the stadium are likely to be objectionable to the people of neighbourhood.

III. FUNCTIONAL ANALYSIS

The exterior appearance of a building is very important but it is second in importance to its functional design. Functionally, the stadium is an athletic field surrounded by seats. Arena is the central feature of design. Its relationship with the requirements and facilities of spectators, participants and administration is very important. Each element in the set up has a specific function to perform and efficiency and economy depend upon its size, form and arrangement in the

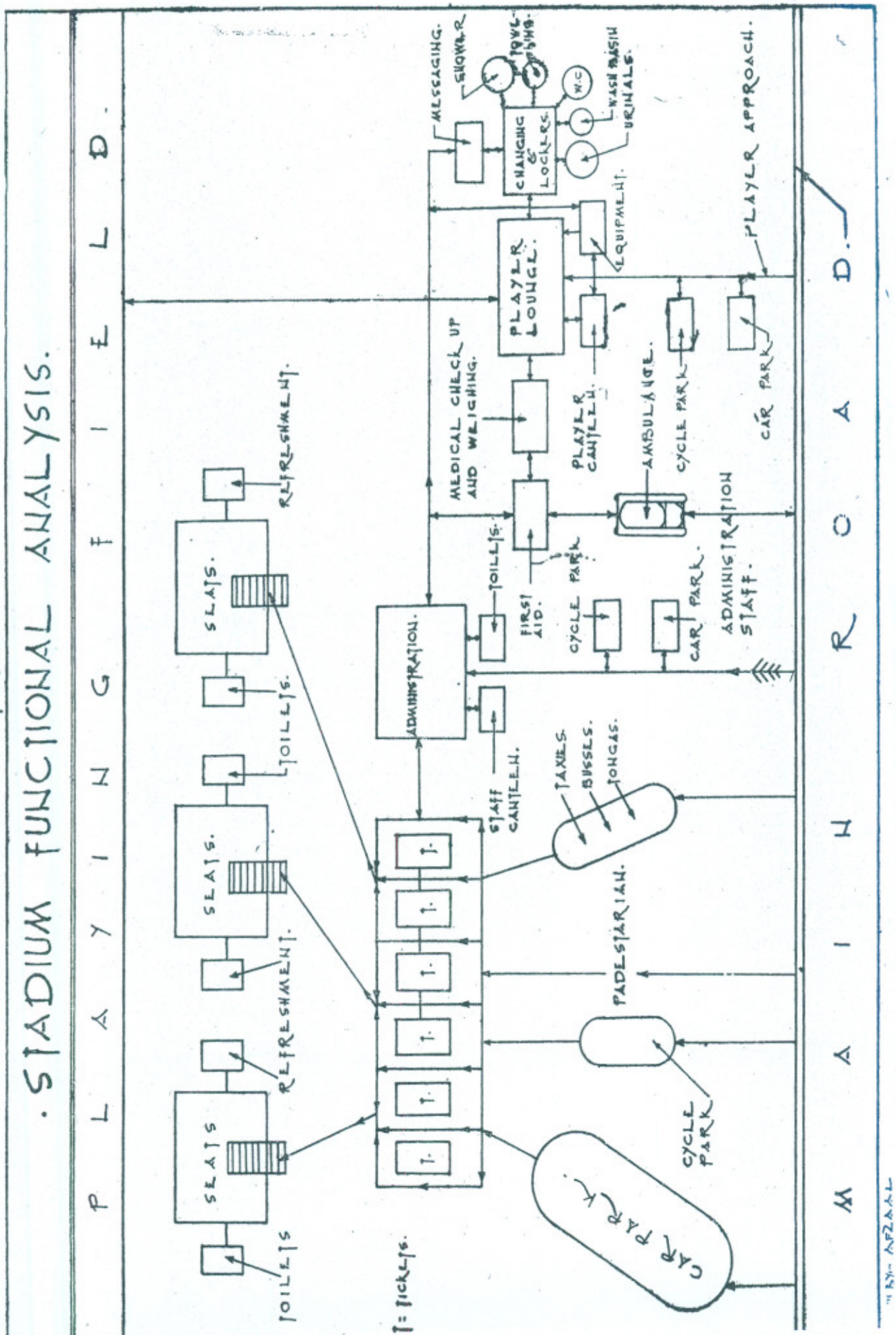


FIG.2.
STADIUM FUNCTIONAL ANALYSIS.
PLAYING FIELD.
MAIN ROAD.
SEATS.
TOILETS.
REFRESHMENT.
T = TICKETS.
ADMINISTRATION.
STAFF CANTEEN.
TOILETS.
FIRST AID.
CYCLE PARK.
CAR PARK.
ADMINISTRATION STAFF.
MEDICAL CHECK UP AND WEIGHING.
PLAYER CANTEEN.
PLAYER LOUNGE.
AMBULANCE.
CYCLE PARK.
CAR PARK.
EQUIPMENT.
MESSAGING.
SHOWER.
TOILETS.
CHANGING & LOCKERS.
W.C.
WASH BASIN URINALS.
PLAYER APPROACH.
TAXIS.
BUSES.
LORRIES.
PEDESTRIAN.
CYCLE PARK.
CAR PARK.

integrated whole. Diagramatic analysis of fundamental requirements their inter relationship and circulation aspects for spectators as well as participants are given in figure number 2. These general relationships almost hold good for all types of stadiums but peculiarities of the selected site, the number of spectators to be accommodated and anticipated expansions etcetra are very significant factors for effective solution of any particular problem.

IV. FIELD DESIGN

I. Popular outdoor games in Pakistan and their fields.

The field of sports and games is very vast and only popular outdoor sports and games played in Pakistan have been included in this paper which does not cover cycle racing and horse racing.

(a) *Athletics.*

The sports of athletics which comprises competitions in walking, running, jumping and throwing is really the most natural of all sports. Its history goes back to prehistory period and we have details of olympic games during Greek and Roman periods. The first modern olympics took place at Athens in 1896 and women events were included in 1928. Athletics events have now become standardized. Races are a series of recognised distances and throwing and jumping are held in accordance with internationally agreed upon rules. Standard layout and construction details for track and field events are given in Figures No. 3 and 4.

(b) *Cricket.*

Cricket can claim a longer history than any other game. Historians have attempted to trace its origin in various games played in India before the advent of English period, but it is certain that this game in its present form was introduced by the English in this subcontinent. Cricket is not taken with much enthusiasm except in England, Australia, South Africa, West Indies, India and Pakistan. Within a few years of Independence, Pakistan has established itself in the cricket world and, due to outstanding international victories, the cricket has acquired the role of a national game in our country.

The game does not offer the speed loving era a great deal of action. It is entirely dependent on fine weather and many games have to be left inconclusively drawn. No specific dimensions have been laid down for a cricket field but the game requires, for safety, a field approximately 400 ft in dia, and clear of obstructions. The pitch proper should be a perfectly level area extending about 100 ft in width so that the wickets can be moved from side to side thus enabling the grass to recover from hard use to which it is subjected. The details of cricket field and pitch are given in figure No. 5.

FIG. 3.

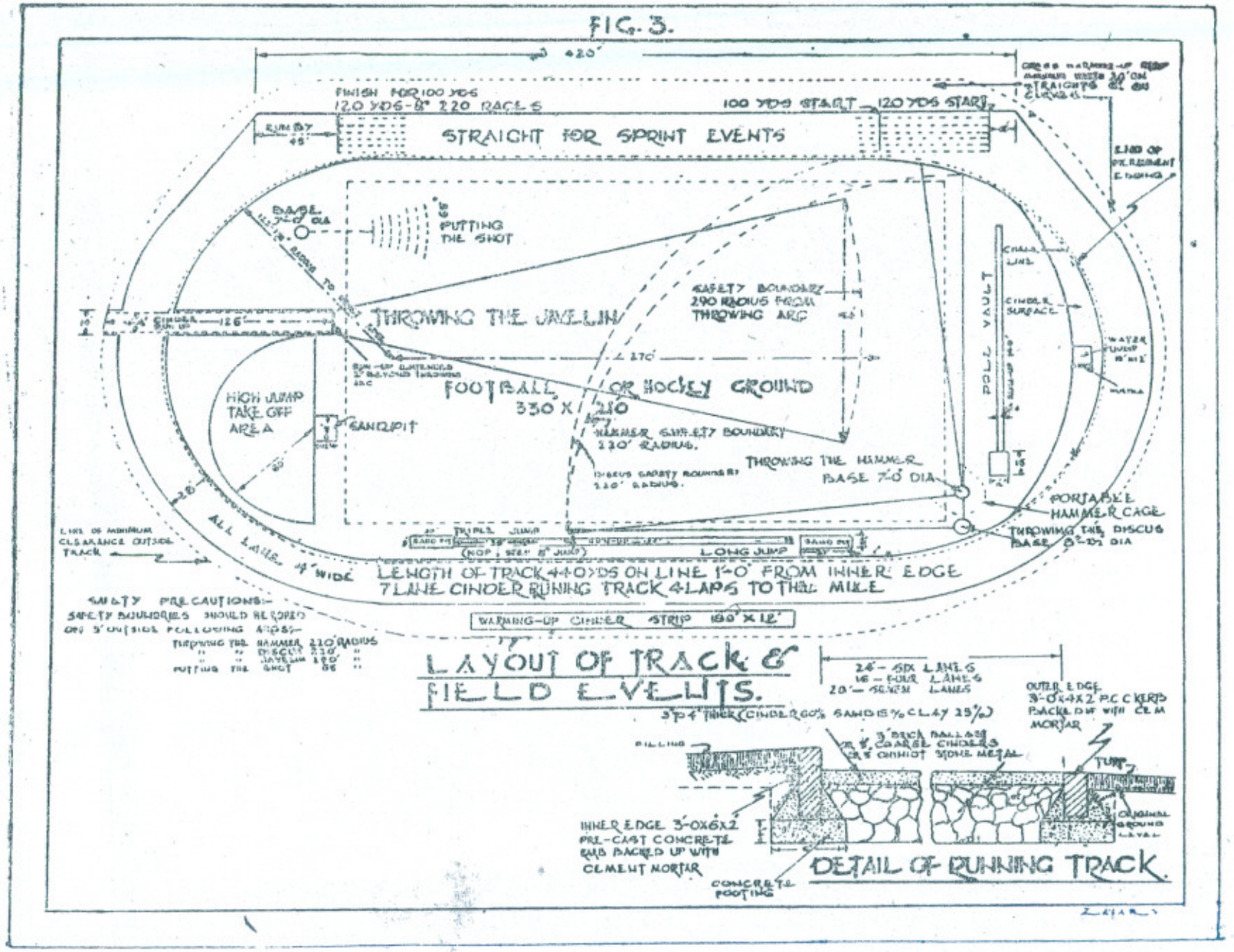

420'
FINISH FOR 100 YDS
120 YDS-8" 220 RACES
100 YDS START
120 YDS START
STRAIGHT FOR SPRINT EVENTS
RUN IN 45'
BASE 7'-0" DIA
PUTTING THE SHOT
THROWING THE JAVELIN
SAFETY BOUNDARY 290 RADIUS FROM THROWING ARC
CINDER RUN-UP 126'
RUN-UP EXTENDED 3" BEYOND THROWING ARC
FOOTBALL OR HOCKEY GROUND
330 X 210
HAMMER SAFETY BOUNDARY 230' RADIUS.
HIGH JUMP TAKE OFF AREA
SANDPIT
DISCUS SAFETY ROUNDED AT 230' RADIUS.
THROWING THE HAMMER BASE 7'-0" DIA
POLE VAULT
CHALK LINE
CINDER SURFACE
WATER JUMP 12'-0" X 2'
PORTABLE HAMMER CAGE
THROWING THE DISCUS BASE 8'-2½" DIA
LINE OF MINIMUM CLEARANCE OUTSIDE TRACK
ALL LANES 4' WIDE
TRIPLE JUMP
LONG JUMP
LENGTH OF TRACK 440 YDS ON LINE 1'-0" FROM INNER EDGE
7 LANE CINDER RUNNING TRACK 4 LAPS TO THE MILE
WARMING-UP CINDER STRIP 180' X 12'
SAFETY PRECAUTIONS:-
SAFETY BOUNDARIES SHOULD BE ROPED ON 3' OUTSIDE FOLLOWING ARCS:-
THROWING THE HAMMER 230' RADIUS
" " DISCUS 230' "
" " JAVELIN 180' "
PUTTING THE SHOT 65' "
LAYOUT OF TRACK & FIELD EVENTS.
24' - SIX LANES
16' - FOUR LANES
20' - SEVEN LANES
OUTER EDGE 3'-0"x4"x2" P.C. KERB PACKED UP WITH CEM MORTAR
3'-4" THICK (CINDER 60% SAND 15% CLAY 25%)
3' BRICK BALLAST
6" COARSE CINDERS
9" CINDER STONE METAL
FILLING
TURF
ORIGINAL GROUND LEVEL
INNER EDGE 3'-0"x6"x2" PRE-CAST CONCRETE KERB BACKED UP WITH CEMENT MORTAR
CONCRETE FOOTING
DETAIL OF RUNNING TRACK.

FIG. 4.

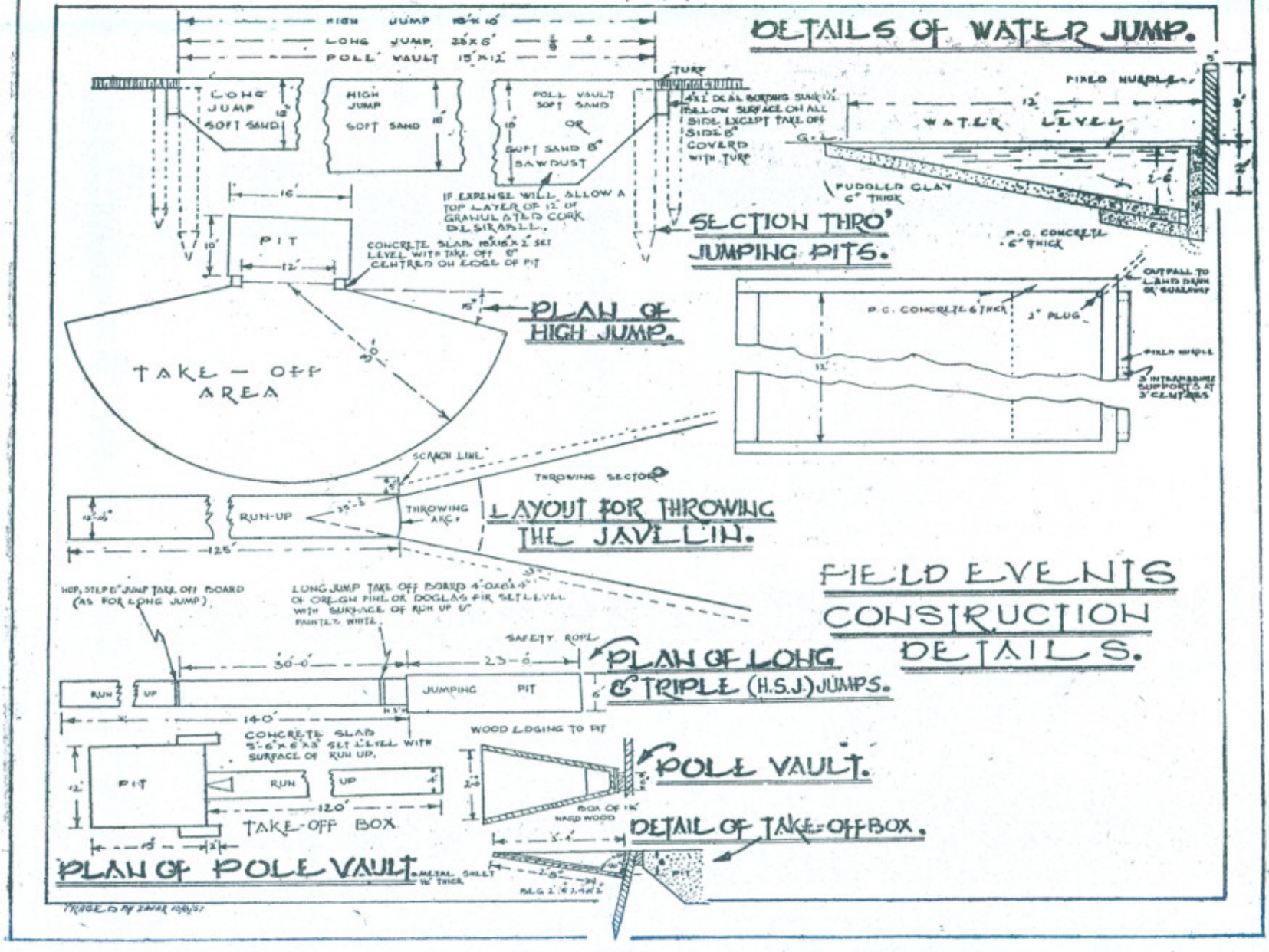
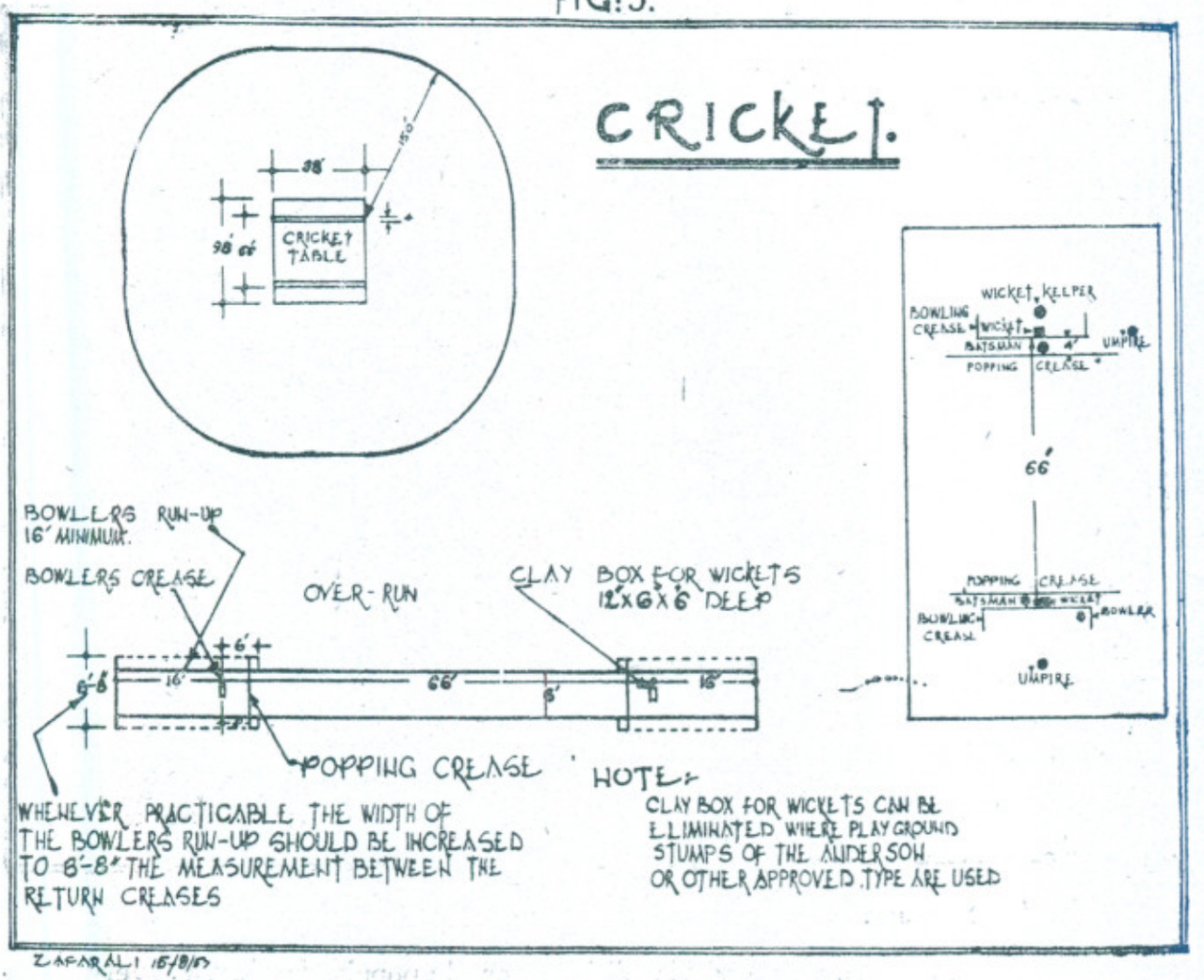

HIGH JUMP 15'x10'
LONG JUMP 25'x8'
POLE VAULT 15'x12'
LONG JUMP SOFT SAND
HIGH JUMP SOFT SAND
POLE VAULT SOFT SAND OR SOFT SAND & SAWDUST
TURF
4"x1" DEAL BORDING SUNK 1½" BELOW SURFACE ON ALL SIDES EXCEPT TAKE OFF SIDES COVERD WITH TURF
IF EXPENSE WILL ALLOW A TOP LAYER OF 12" OF GRANULATED CORK DE SIRABELL.
PIT
CONCRETE SLAB 10'X6'X2" SET LEVEL WITH TAKE OFF & CENTRED ON EDGE OF PIT
TAKE-OFF AREA
PLAN OF HIGH JUMP.
SECTION THRO' JUMPING PITS.
DETAILS OF WATER JUMP.
FIXED HURDLE
WATER LEVEL
PUDDLED CLAY 6" THICK
P.C. CONCRETE 6" THICK
OUTFALL TO LAND DRN OR GUARWAY
P.C. CONCRETE 6 THKS
2" PLUG
FIXED HURDLE
3 INTERMEDIATE SUPPORTS AT 3' CENTRES
SCRATCH LINE
THROWING SECTOR
RUN-UP
THROWING ARC
125'
LAYOUT FOR THROWING THE JAVELIN.
FIELD EVENTS CONSTRUCTION DETAILS.
HOP, STEP & JUMP TAKE OFF BOARD (AS FOR LONG JUMP)
LONG JUMP TAKE OFF BOARD 4'-0"x0'-4" OF OREGON PINE OR DOUGLAS FIR SET LEVEL WITH SURFACE OF RUN UP & PAINTED WHITE.
SAFETY ROPE
30'-0"
23'-6"
RUN
UP
JUMPING PIT
140'
PLAN OF LONG & TRIPLE (H.S.J.) JUMPS.
CONCRETE SLAB 5'-6"x6'x3" SET LEVEL WITH SURFACE OF RUN UP.
PIT
RUN
UP
120'
TAKE-OFF BOX
WOOD EDGING TO PIT
POLE VAULT.
BOX OF 1¼" HARD WOOD
DETAIL OF TAKE-OFF BOX.
PLAN OF POLE VAULT.
METAL SHELF ¼" THICK
PIT

FIG: 5.



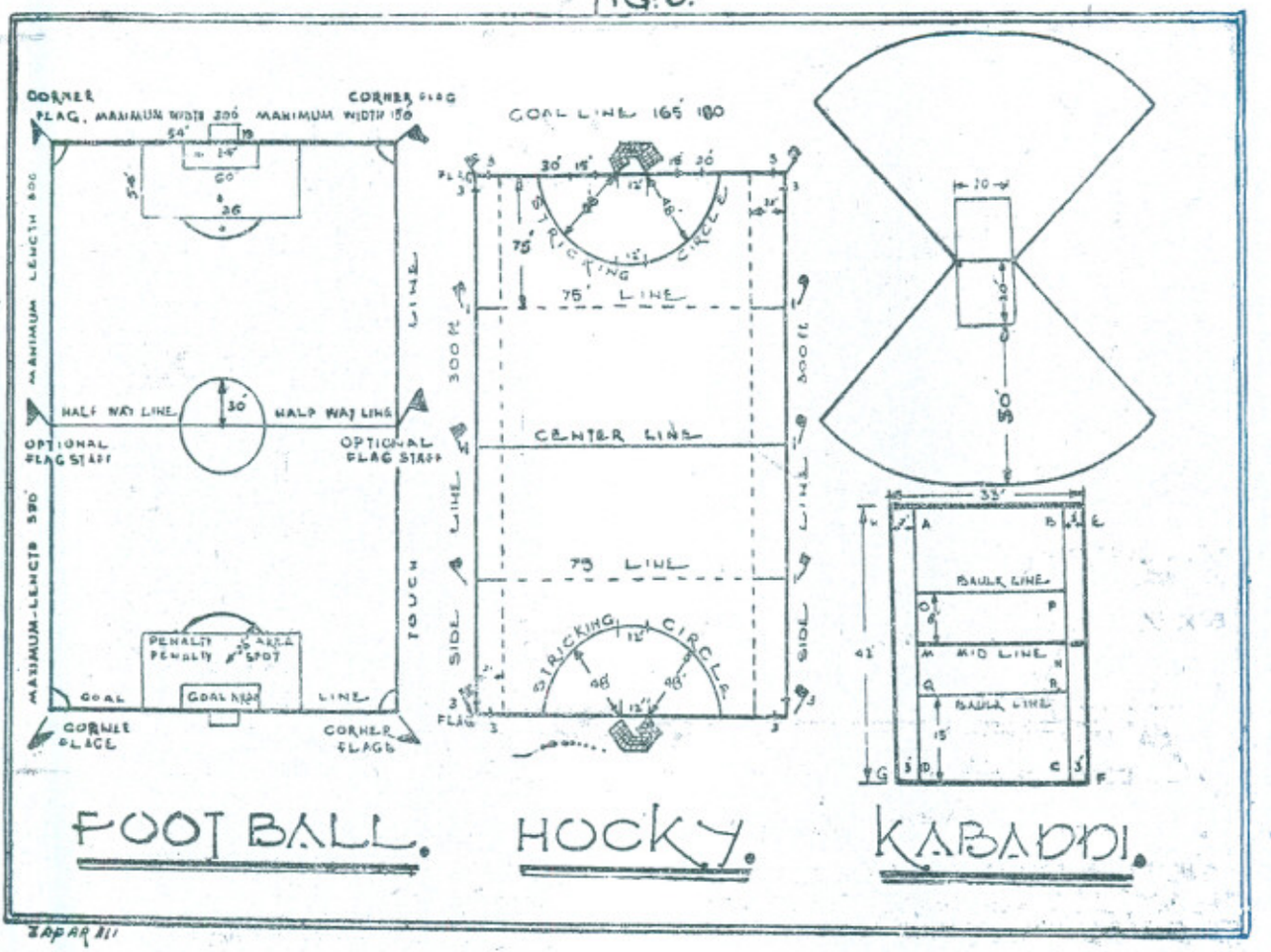
(c) ***Foot Ball.***

It is impossible to say that just who first thought of foot ball. Attempts have been made to trace the game back to Romans but it is certain that the game made its appearance in this sub continent due to the English. The growth and popularity of foot ball during this century has heen remarkable and at present the game is played in various styles in different parts of the world. Association foot ball is usually played in Pakistan and its field is shown in Figure No. 6.

(d) *Hockey.*

Hockey originated in Persia and is supposed to be the oldest stick and ball game in the world. It was organised in England about a century ago and since has spread to many countries. It has been played in Olympics since 1908 and India has dominated practically every competition but Pakistan displayed an outstanding skill in this game of ball and stick during the last Olympics at Melbourne and the game is coming into its own. The details of field are given in Figure No. 6,

FIG. 6.



(e) *Lawn Tennis.*

Tennis "the game of Kings" is extremely popular in almost every country in the world. As its name implies it was originally intended to be played on grass but though the name "Lawn Tennis" has been retained, it is now played on variety of surfaces, turf, clay, dirt, water bound macadam, concrete and bitumenous surface as well as indoors on wood. Diagram No. 7 gives details of single and double courts.

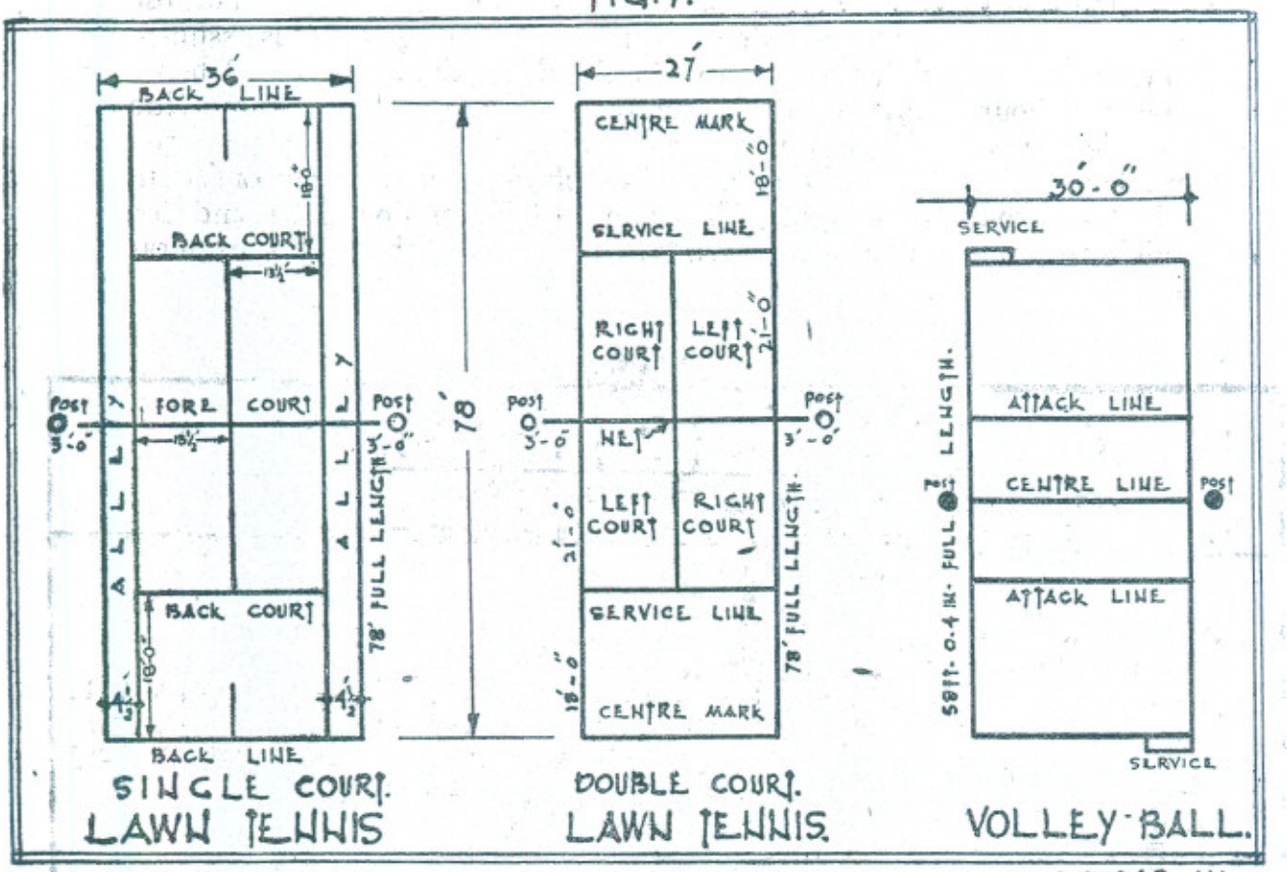
(f) *Volley Ball.*

Volley ball is a game of middle classess and can be played on any level surface large enough for a court the official dimensions of which are given in drawing. Generally the game is not likely to attract large crowds but any important meet can be easily organised in athletics or cricket stadium.

(g) *Kabbadi, Wrestling and Boxing.*

Kabbadi is an indigenous game and can be played on turf or loosened soil. Its inclusion in tournaments is more of a courtesy and possibility of its large scale development seems remote. Wrestling is an

FIG: 7.



ZAFFAR ALI

individual combat and Gama's conquests created international blaze of glory. Loosened soil is the most economical and popular surface. Spectators prefer closer view and arena could be suitably provided in any stadium.

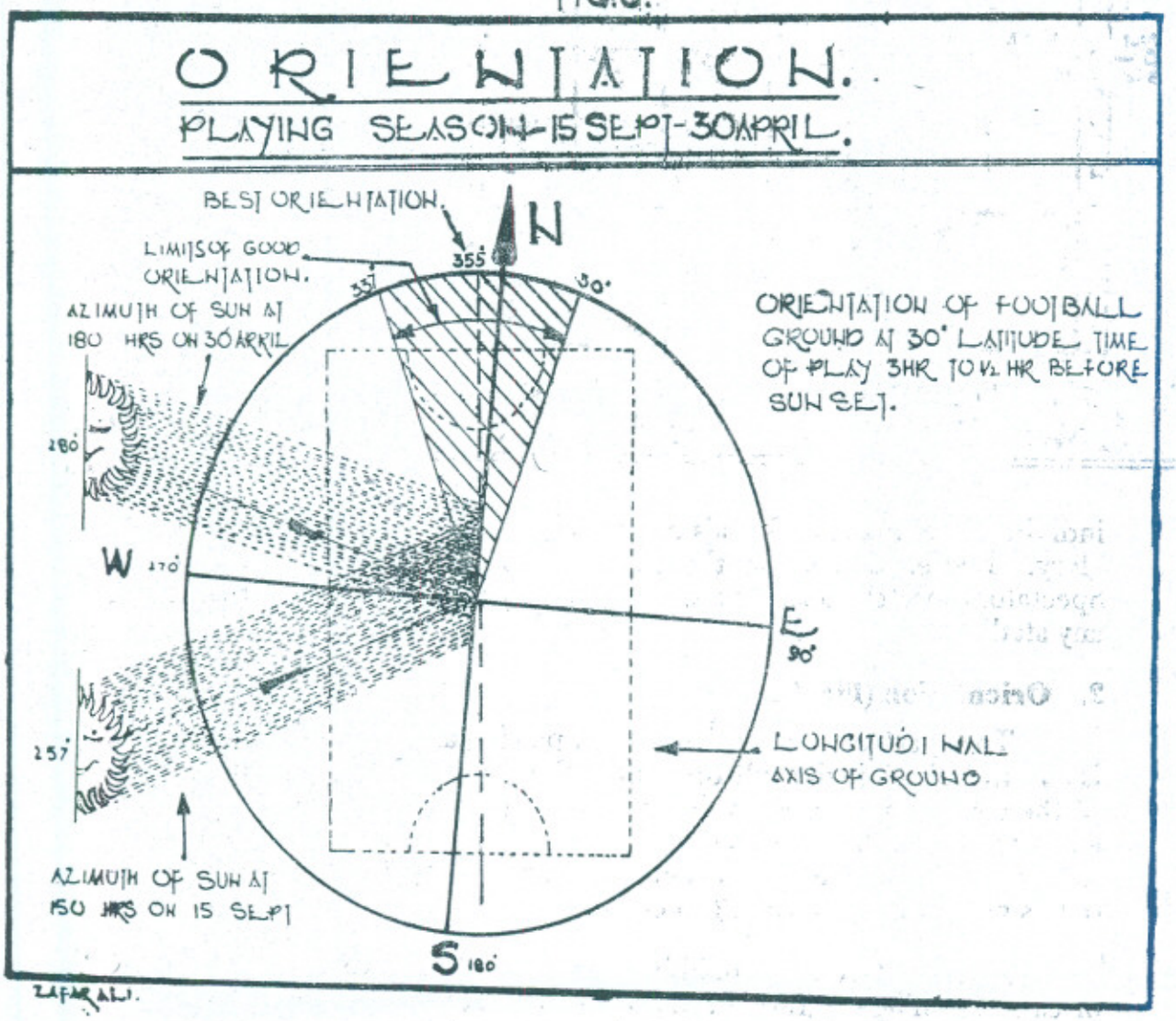
2. Orientation (Field).

The perfect orientation for all playing areas under all conditions is an ideal which is difficult to attain. Topography, shape of area, time of the day the ground is to be used, geography and other conditions enter into the problem of orientation. Keeping these variables in mind one should orient courts and fields in such a manner that maximum protection is given to the players who need it the most.

Fields and courts should be orientated so that the late afternoon or early morning sun rays intersect the general path of the ball flight at an angle of approximately 90°. In rectangular fields and courts, the general pattern of the balls flight is parellel to the long axis. Therefore the long axis should be generally at right angles to the late afternoon sun rays. The sun set position for the mid season of the sports inolved should be located and the field or court orientated accordingly. Orientation depends upon latitude and hour of play which within reasonable limits be adjusted to finish the game before dusk.

Figure No. 8 gives orientation for foot ball field. Geographically Pakistan is situated between 24° and 36° latitude and for the purpose of orientation, average latitude of 30° is taken. Playing season is assumed to extend from 15th September to 30th April and time of play as 3 hours to half an hour before sun set. When the stadium is designed to provide facilities for several sports extending over major part of the year the problem of orientation becomes more difficult and a compromise in orientation must be adopted. The sport which predominates and for which the sun has the most harmful effect is given the chief consideration.

FIG. 8.



3. Grading.

Grading is the process of changing the existing levels of the area Most lands are rough and require gradation which facilitates the removal of surface water and gives even surface for playing. In accordance with the fundamentals of earth work, the amount of "cut" should if possible balance the amount of "fill" in order to avoid the necessity

of hauling away the excess earth or hauling in the needed material. The slope of the top should be gradual so that it will not be washed away during or after a heavy rain. A grade of 1 in 100 is usually satisfactory on turf and should not extend more than 200 to 300 ft otherwise ruts will be formed by the water running off after a heavy rain fall. This can be done by providing suitable net work of catchment drains.

4. Drainage

Treatment of the playground varies with the type of surface and the climatic conditions. Water allowed to collect and stand on the ground interferes with play and actually makes the area unfit for use. For rain water, a good general rule is to limit the slope one percent to three percent. Any slope less than one percent is too flat and grade in excess of three percent tends to cause erosion. During dry season, irrigation system may be required to keep the turf in a springy condition.

Water logging and ground water lying near the surface of ground tend to create soggy and uneven surface which does not permit satisfactory play. Where this condition exists a sub drainage system is required. While the primary purpose of sub surface drainage system is the removal of excessive water, it also aerates the soil thereby sweetening it and stimulating the growth of turf. Too much sub drainage on the other hand deprives the turf of needed moisture.

Specific play areas must be relatively level with a gradual slope, which may be from end to end, side to side, from one corner to the diagonal corner on the opposite end, pyramidal, valley, ridge, hip or gable roof type, as shown in figure No. 9. Depending on soil and surface conditions the crown height of a cricket field is about 18 inches and hockey or foot ball field about 12 inches. If the sub soil drainage is poor the crown should be higher. Drainage of the track is exceedingly important because its moisture content is very vital. Drains to take care of surface water from ground boardering the track should be provided as needed along the inner and outer edges of the track to prevent water from flooding it.

5. Surfacing.

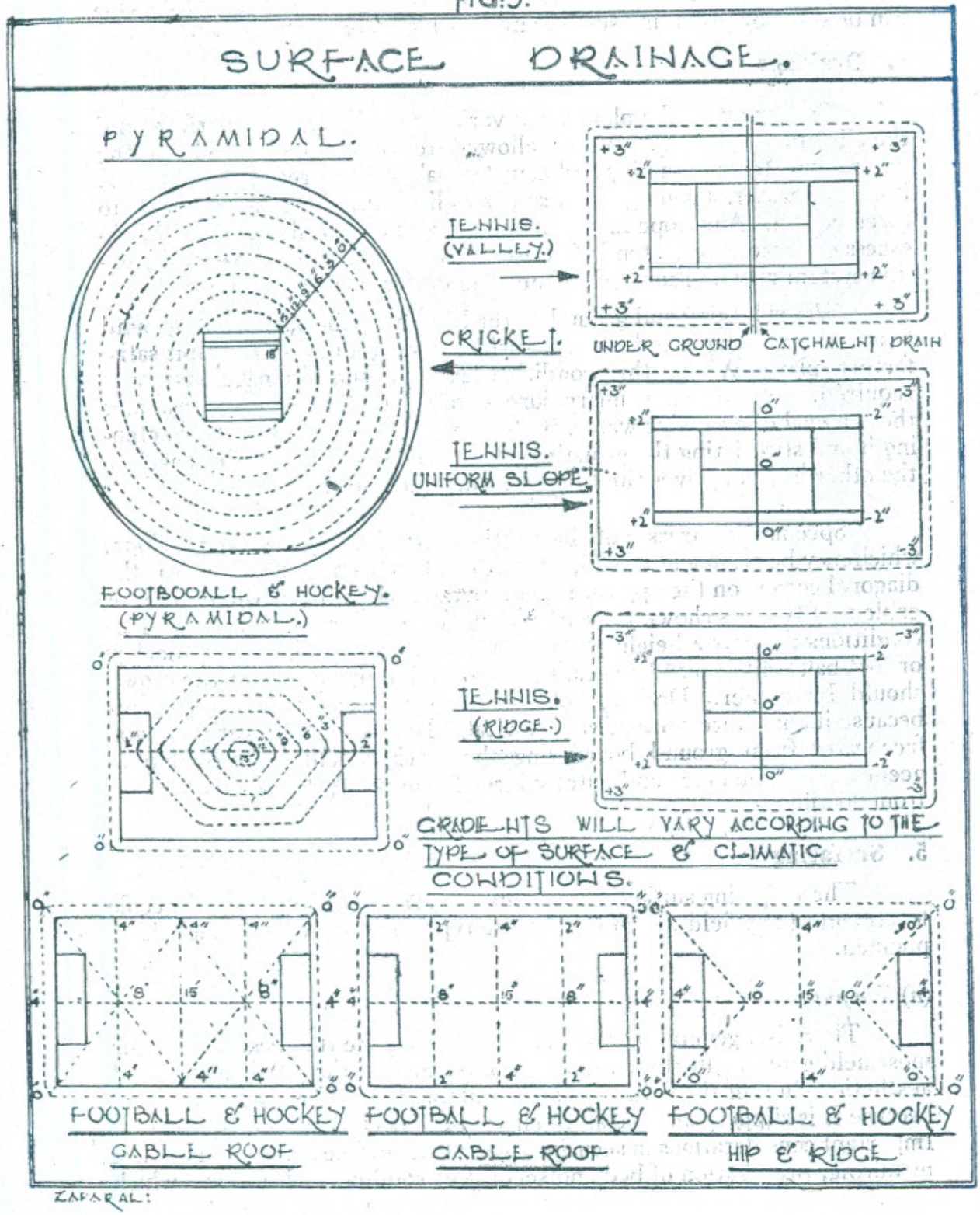
The following surface treatments are generally given and specific treatment of any field depends upon the type of activity for which it is planned.

(a) Turfing.

There is a general agreement that grasses are the best cover for most field games. Further the turf contributes to the psychological and aesthetic values of the field. It is not suitable for plays soon after a rain because it is slippery and moisture effects players clothing and equipment. Important considerations in securing a good turf surface are grading, silting, manuring, preparation of bed and seeding or sodding such strains which

thrive in the locality and are resistent to intensive use. The grass is a crop and cannot be expected to give a good yield if it receives nothing

FIG:9.



in return and care must be taken in mowing, rolling, feeding and watering the turf. If sufficient care is not taken the grass will rapidly weaken and die off and coarse and undesirable weeds will move in. Foot ball, hockey and cricket fields are subjected to severe use and constant rolling leads to "capped" surface preventing the free circulation of air and moisture, killing the soil bectaria, diminishing the root action and resulting in weeds and patchy surface. In such cases, spike rolling and spike harrowing or periodic use of other aerating implements is necessary in routine maintenance with renovation by reseeding or returfing where necessary. Turf is ruined if used in early spring. Except in tennis courts and cricket pitches the turf should not be mowed too closely.

(*b*) *Running Tracks.*

The running track is a feature of practically every athletic field. Important considerations in track construction include temperature, rainfall and soil conditions, which vary in different parts of the country. These variables influence the provision for drainage, the banking of the track surface, and the types of materials used for the track. A well constructed running track should be put down in three layers or strata. (1) A soling layer, varying from 3" to 10" depending upon local conditions, consisting of coarse rubble, stone brick or brick ballest, levelled and thoroughly rolled. (2) A middle layer of 5" to 10" cinders of rather coarse grade but without heavy clinkers and well rolled. (3) The top dressing 3" to 4" of finely screened cinder 1/4" to 3/8" mesh with a binder usually of clay, loam or ashes, depending upon local weather conditions and availability of material. Too much soil robes the surface of resiliency, too little soil allows it to pack and role. Figure No. 3 gives cross section of a typical track.

(*c*) *Sand Pits.*

Sand pits are used for jumping events and consist of soft sand or soft sand mixed with wood shavings and require occasional disinfecting.

(*d*) *Natural Soils mixed with sand and Clay.*

In some places local soil mixed with sand and clay and rolled gives low cost surfacing.

(*e*) *Stabilized Soils.*

When turf cannot be grown due to local conditions or when specialised uses make truf impracticable existing loose soils should be stabilized. The stabilizing agents more generally used are (*a*) Rosin (*b*) Cement (*c*) Bitumen. Mix will vary according to the type of soil and moisture contents etcetra.

(*f*) *Abbrasive Materials.*

Crushed stone or *bajree*, brick ballest, gravel and graded cinders mixed with sand and clay and adequately rolled give playable surfaces.

(g) *Bitumenous Conerete*

The charactertistics of bitumenous ccncrete are such that by changes in aggregates or methods of construction it can provide a reasonably resilient or an extremely hard surface. Finish of jute, cork, wood pulp, asbestos, bound with bitumen give resilient surface. *Bajree* and crushed stone mixed with heavy bodied high point bitumen give a hard non resilient surface.

(h) *Cement Concrete Plain or Renforced.*

Cement Concrete is desirable when permanent, durable, and extremely hard surface is required and the usual mix is 1:2:4.

6. Lighting.

The growing interest in sports and other multiuses of stadiums such as police tatoos, open air plays etcetra, are certain to result in a demand for the lighting for evening use. Occupation or unfavourable heat during the day creates desire to participate or become a spectator during the evening. Lighting should provide ample visibility for both players and spectators without objectionable glare. It presents a different problem because there are no walls and ceilings to reflect light into a central area and lighting intensity which varies from 15-25 candle powers depends on the size of the field and the type of contest. Type of lighting, height, number and spacing of poles, distance from the field, voltage and other highly technical matters, are best determined by an electrical engineer. In planning out door artificial lighting several points should be observed such as :—

(a) Direct light rays should not strike the eyes of players or spectators, players being given preference.

(b) Glare should be avoided.

(c) All shadows and spottiness should be eliminated.

(d) No obstruction should interfere with the lines of vision.

7. Fencing.

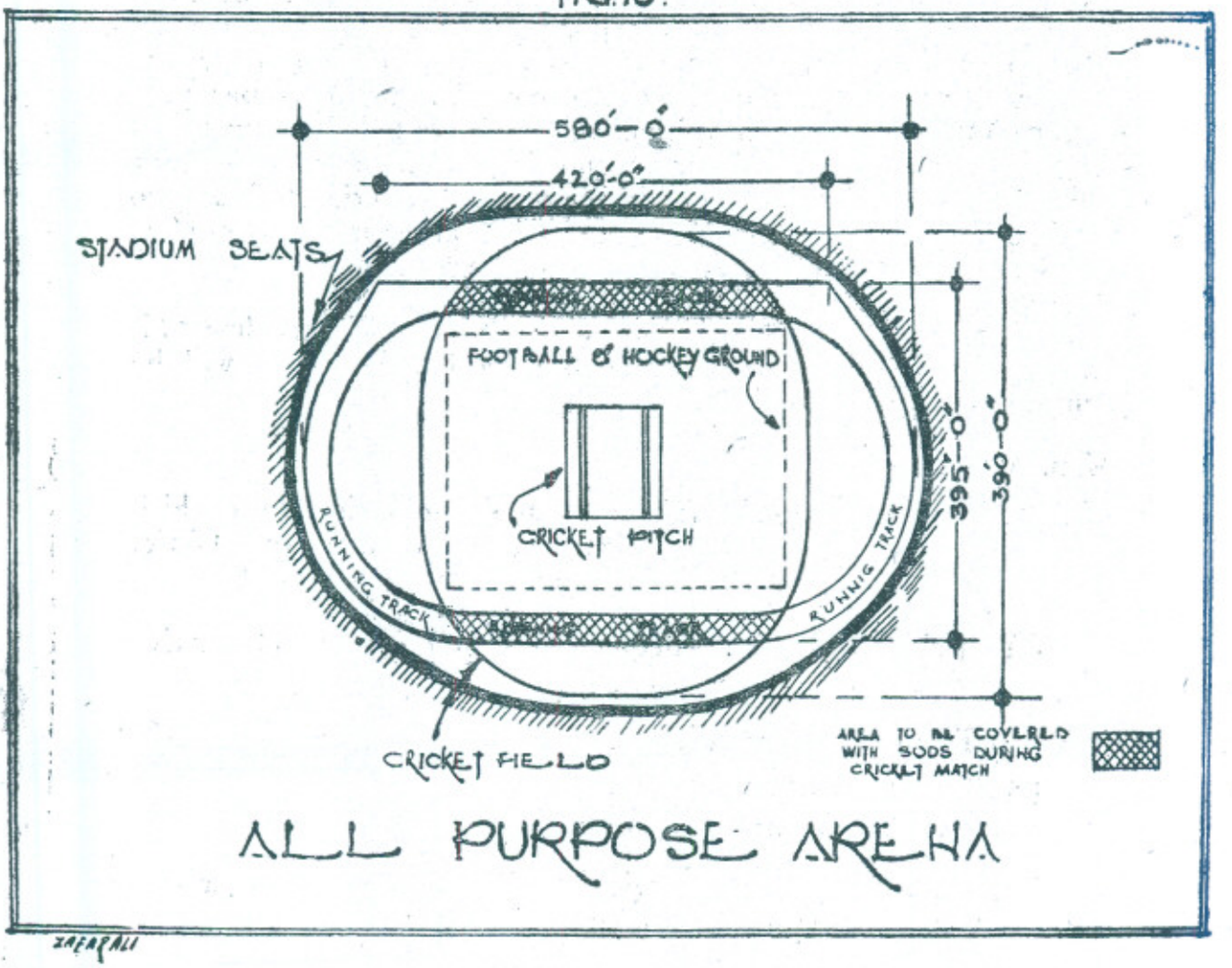
When the seating structure partially encircles the ground some sort of *purdah* is necessary as a barrier to persons who have not gained admission to the performance. Improvised *purdahs* of hessian or *Shahmianas* have the lightness, ease and flexibility of construction to suit the demands of temporary seats. Permanent *purdah* walls have greater initial cost but durability and economy in maintenance and can be designed to match with the exterior of the stadium. When there is a passage in front of seats it is desirable to seperate the grounds by sinking the passage by provding mote or some sort of woven wire fence in order to eliminate tress passing, vandalism, interferenge in game and to protect the players.

8. Multipurpose Field.

In our country cricket has acquired greater popularity and during international tests it is likely to attract upward of 30,000 fans. Gatherings for important athletics, foot ball or hockey meets are not so spectacular. In any city the cricket test or other important competitive events are held once or twice a year and as such the stadium is not likely to be used for more than a week or so in any year. The construction cost of about 30,000 seats will be well over Rs. 20 lacs with annual maintenance and depreciation of about Rs. 60,000/-. The development of seperate seating arrangements for various activities will be very expensive to build and maintain in relation to volume of its use. Position in other countries is different where certain amount of betting is associated with sports and this results in more ticket money and extensive seasonal use.

In view of our sports requirements it is desirable to develope multipurpose field with same seating facilities to serve spectators, equally well, for practically all the events. The inclusion of field events, foot ball and hockey inside the cinder track has proved very satisfactory and is accepted internationally. The laying of cricket field along the side of the

FIG. 10.



athletic area will create problems of seating. Overlapping of both fields is only feasible if some acceptable solution of surface treatments is found. The cricket requires good turf for pitch and unobstructed grassy out field. The athletics area requires cinder track; turf and sand pits. The over lapping portions of cricket field and athletics will result in the clash of surface treatments, though the overlapping portions of track are not likely to receive intensive uses during cricket matches as shown in Figure 10

In order to overcome this difficulty it is suggested that the cinder track and its curbs be laid about 3″ below the rest of the field and during cricket matches the track and sand pits be covered and levelled with turf by transplanting the sods. A plot of about one acre outside the stadium be planted with turf and maintained on the same standard as the turf inside the stadium. During criket matches the turf be cut into sods say 1′×3′ and laid to cover the track and sand pits. After the match, the sods be taken back and any loss of soil made good with addition of fertilizers if necessary. During the match sprinkling of water, sparingly applied, will keep the sods in good condition without spoiling the track. No doubt this will result sacrificing of something of the ideal arrangement either from the stand point of spectators or players. Interest on capital investment, maintenance and depreciation of seating structure with 30,000 seats will amount to about Rs. 2,00,000/- per year while expenditure on additional plot of turf and couple of yearly transpanting operations of sods in track and back will amount to about Rs 10,000/-. The combination of athletic area and cricket field also results in elliptical arrangement which is ideal from seating point of view as described under "shape" vide page 117 of this paper.

In the Lahore Stadium which is being built on the Ferozepur Road, it is proposed to develope 4 arenas and the construction work will be split up in several phases.

(i) *Main Arena.*

A 15′ wide passage will run all around the main arena which will be 610′ dia and enclosed by a high fence of welded steel fabric. It will be adequate to embrace the following events :—

(a) Cricket field with adequate arrangements for alternative cricket pitches.

(b) Two hockey grounds.

(c) Two Foot Ball grounds.

(d) One hockey and one football ground.

(e) Field and track events with one football or hockey ground.

(f) Velodrome and one football or hockey ground.

(g) Various combinations of the above.

(ii) *Athletic Arena.*

The arena will be of international specifications with 8 running cinder traks and adequate provision for other athletic events such as javelin, long jump, discuss, hammer, pole vault, water jump and hop stop and jump eteetra. Sand pits where necessary will be provided and the arena will also enclose one football cum hockey ground.

(iii) *Velodrome.*

The velodrome will be 333.3 meter internal perimeter with size, superelevation and other specifications as per international standards and will enclose kabbadi, wrestling and boxing arenas.

(iv) *Swimming Pool.*

Space is being reserved for future development of a modern swimming pool.

V. SEAT DESIGN

1. Orientation (Seats).

The payers and not the players create a demand for stadium and it is most desirable to protect them from the glare of sun during the normal hours of play. In a true stadium, the playing field is entirely surrounded by the spectators and it is impossible to get all the seats free of sun. It is desirable to protect the spectators at all afternoon hours but perfect conditions are difficult as during the time the field is in use the sun may move through a large angle. Spectators backs towards the sun give best orientation and this is possible by building on the West and South sides of the ground. For accurate orientation careful plotting of the suns altitudes and azimuths during the normal season and playing hours at the particular latitude are involved. Average latitude of Pakistan is 30° N and figure No. 11 gives orientation for the field, suitable for afternoon play throughout the year though such refinement is not justified if obtained at the sacrifice of any other feature.

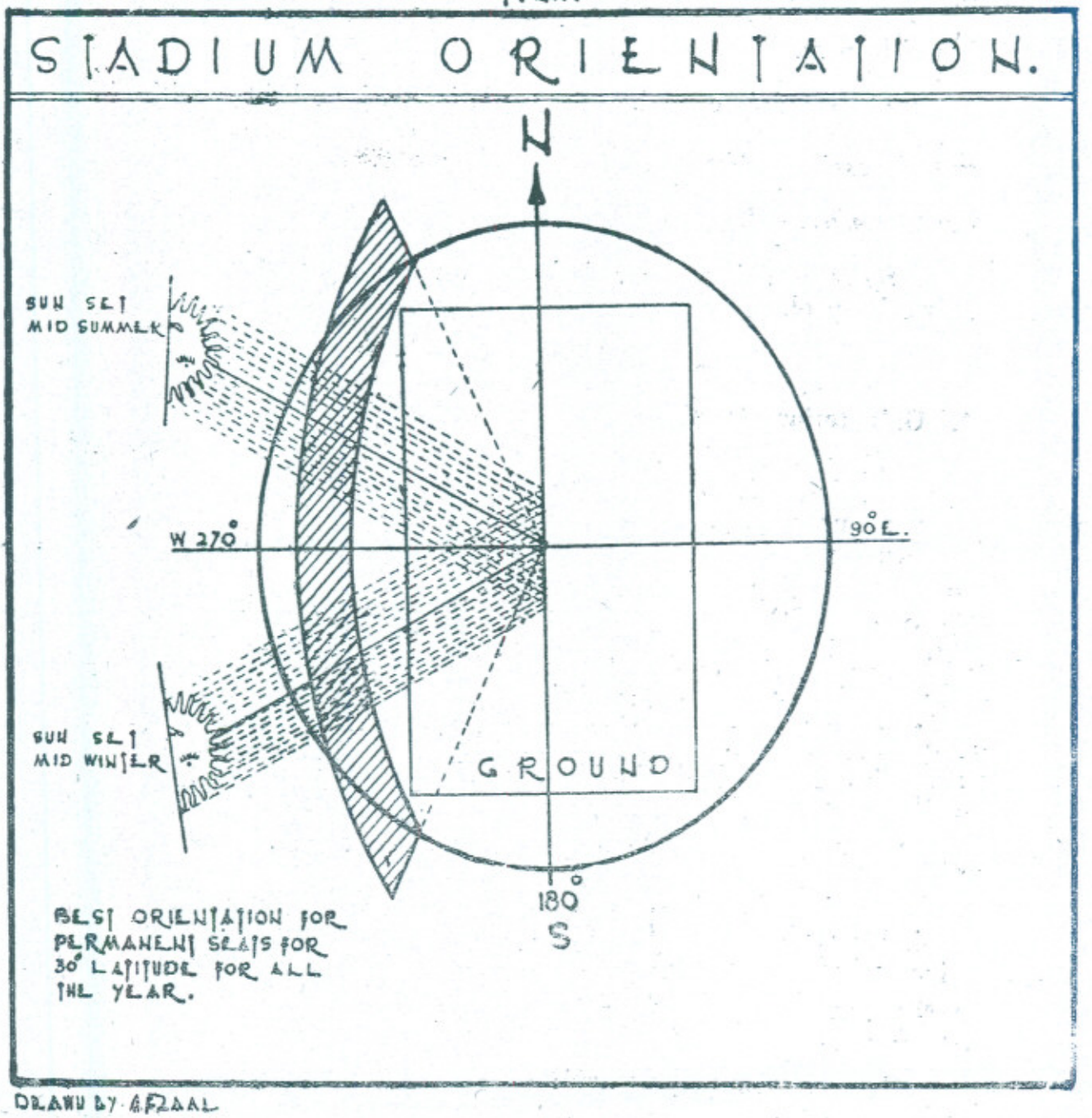
During winter certain amount of sun is welcomed but the seats could have sun shades. Careful plotting of the altitude of the sun will give position for cut back roof which has the advantage of economy, easy cantilivering and freeing the large area from column obstruction as shown in figure No. 12.

2. Distance from playing field.

An ideal seat would be one opposite to centre of action as close to the play as possible and elevated so that the details of the game could be clearly seen. Placing the first row of seats close to the ground line will necessitate higher risers in the successive rows to maintain satisfactory sight lines over the heads of those in front. Therefore the first

row of seats should be placed away from ground edge as far as possible subject to clear and comfortable vision so that the sight clearance can be maintained without making the stadium too steep for convenience and economy.

FIG:11.

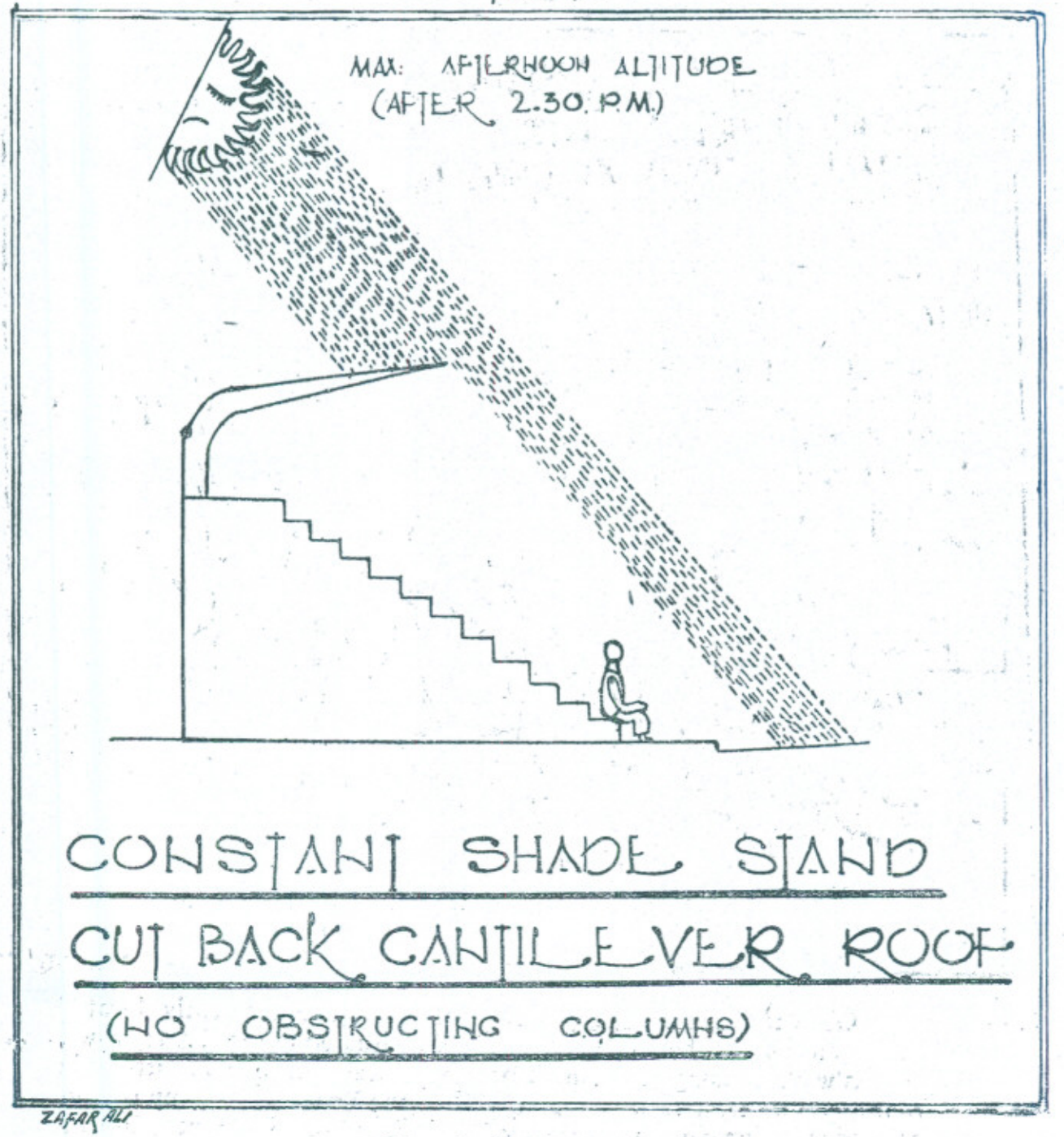


3. Clear vision.

The problem of good view from stadium seats depends on distance, angle of view and freedom from obstructions. During normal day light, foot ball game can be conveniently followed from a distance of about 600 to 700 feet. Movements of cricket and hockey balls are

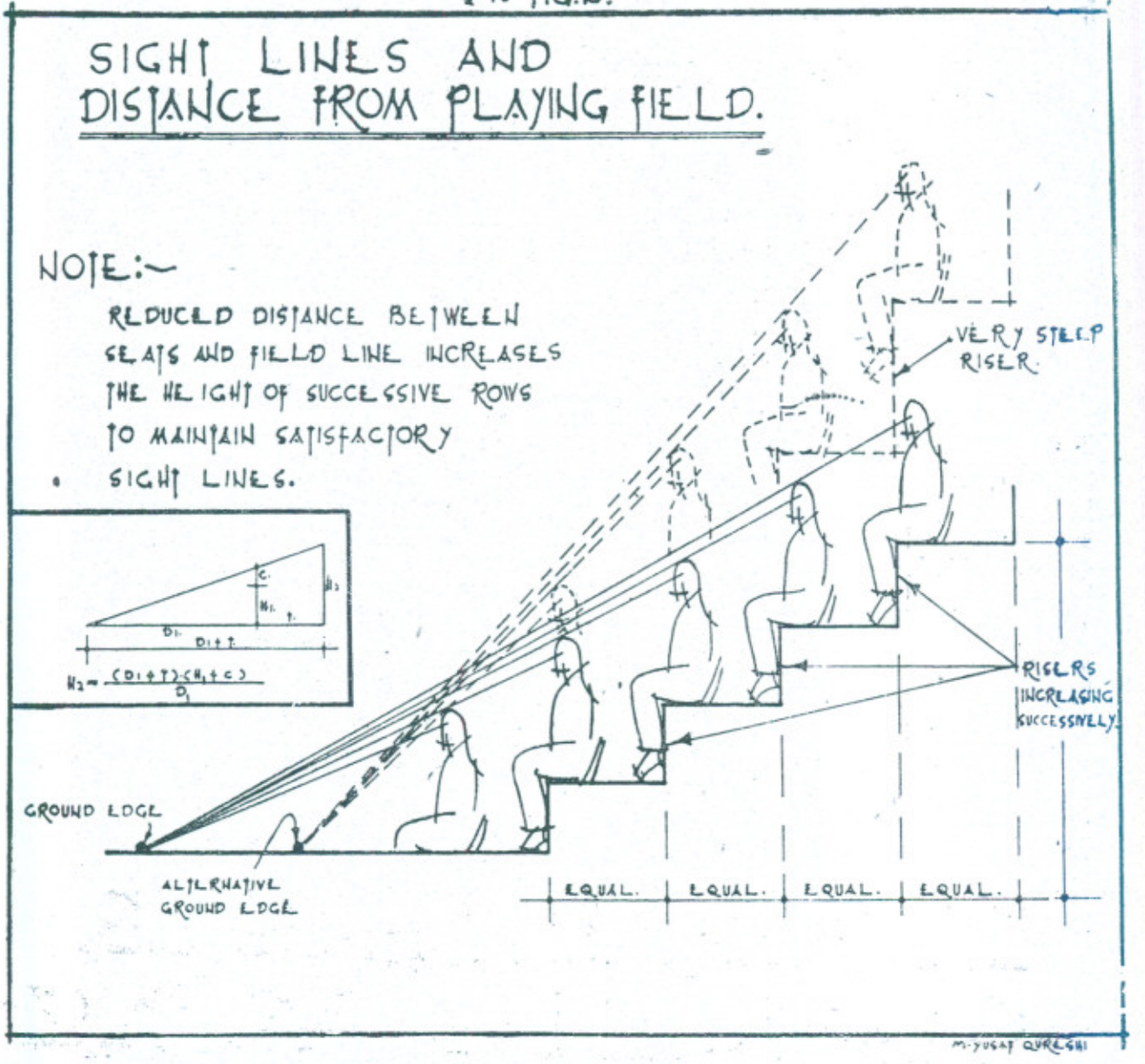
visible from 500 to 600 feet without field glasses. The visibility of an object depends upon the horizontal and vertical angles subtended by the rays of light emanating from the object and received by the spectators eyes. The elevation of an observer above the object to be viewed has an important effect on the angle subtended when the object has an appreciable dimension parellel to the line of sight. In race track, foot ball and cricket, the centre of action involves more than one person and can best

FIG:12.



be seen from elevated seats as seats at ground level have poor view of individual players. Normally the stadium seats are not far enough above the field to appreciably foreshorten the vertical dimensions of the players. For spectators in the side stands, the angle subtended by the immediate field of play along its longitudinal axis, will vary with the nearness of the eye while the angle subtended along the transverse axis will vary with the vertical distance above the heads of the play[illegible] as well as with the horizontal distance.

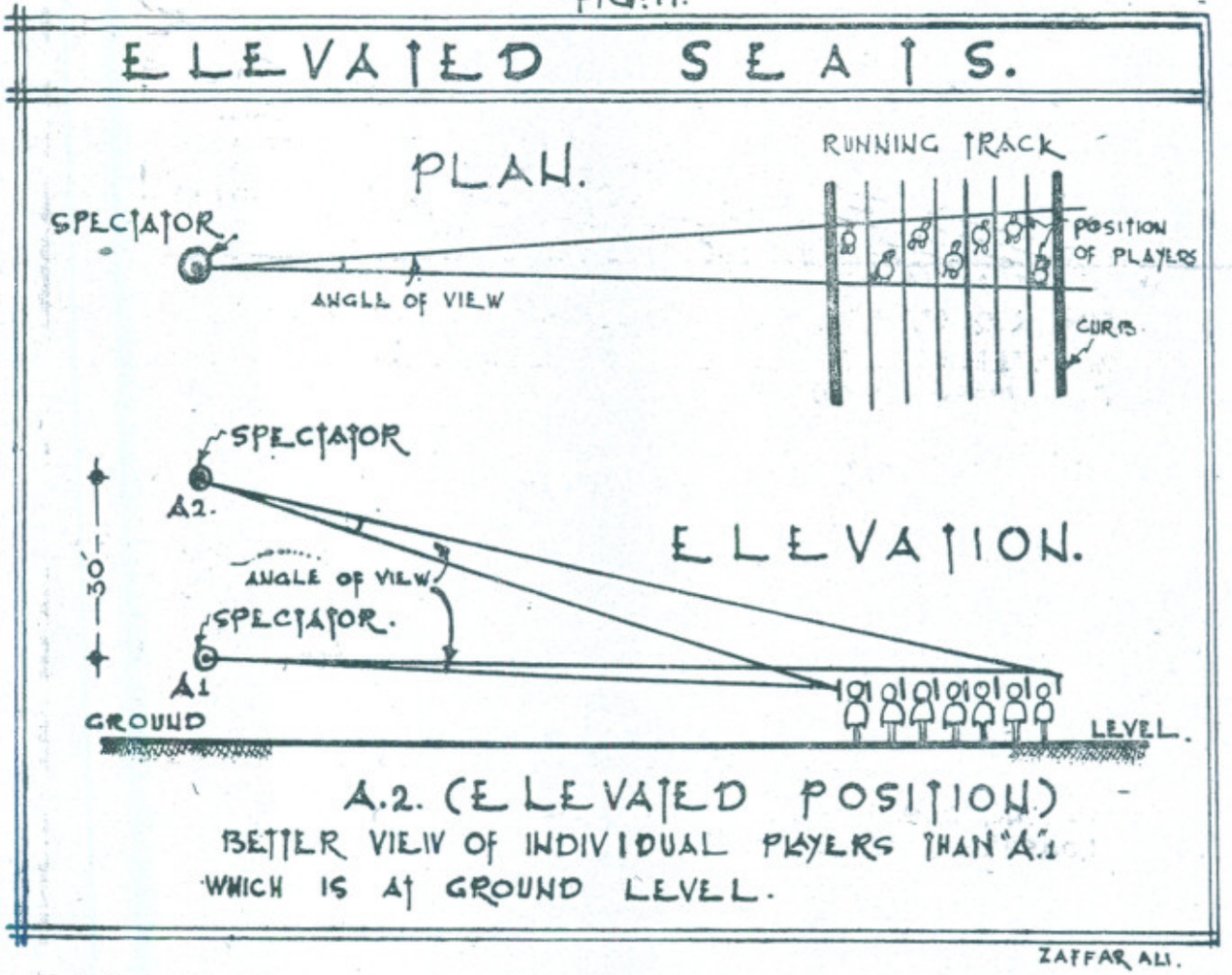
≤ 15 FIG:13.



Obstructions are of several types i.e., inconveniently located railings and pillars, boxes and covered seats situated in the lower rows, persons walking along horizontal passages, heads of people sitting in front etcetra. Best view is obtained when the sight lines to any part of the field of action clear the heads of the spectators in front and the

adequacy of clearance is the important factor in stadium design. Sight lines normal to seats are ordinarily considered and oblique lines to different parts of the stadium are neglected. Oblique sight lines tend to restrict the clear view only when the degree of deflection becomes

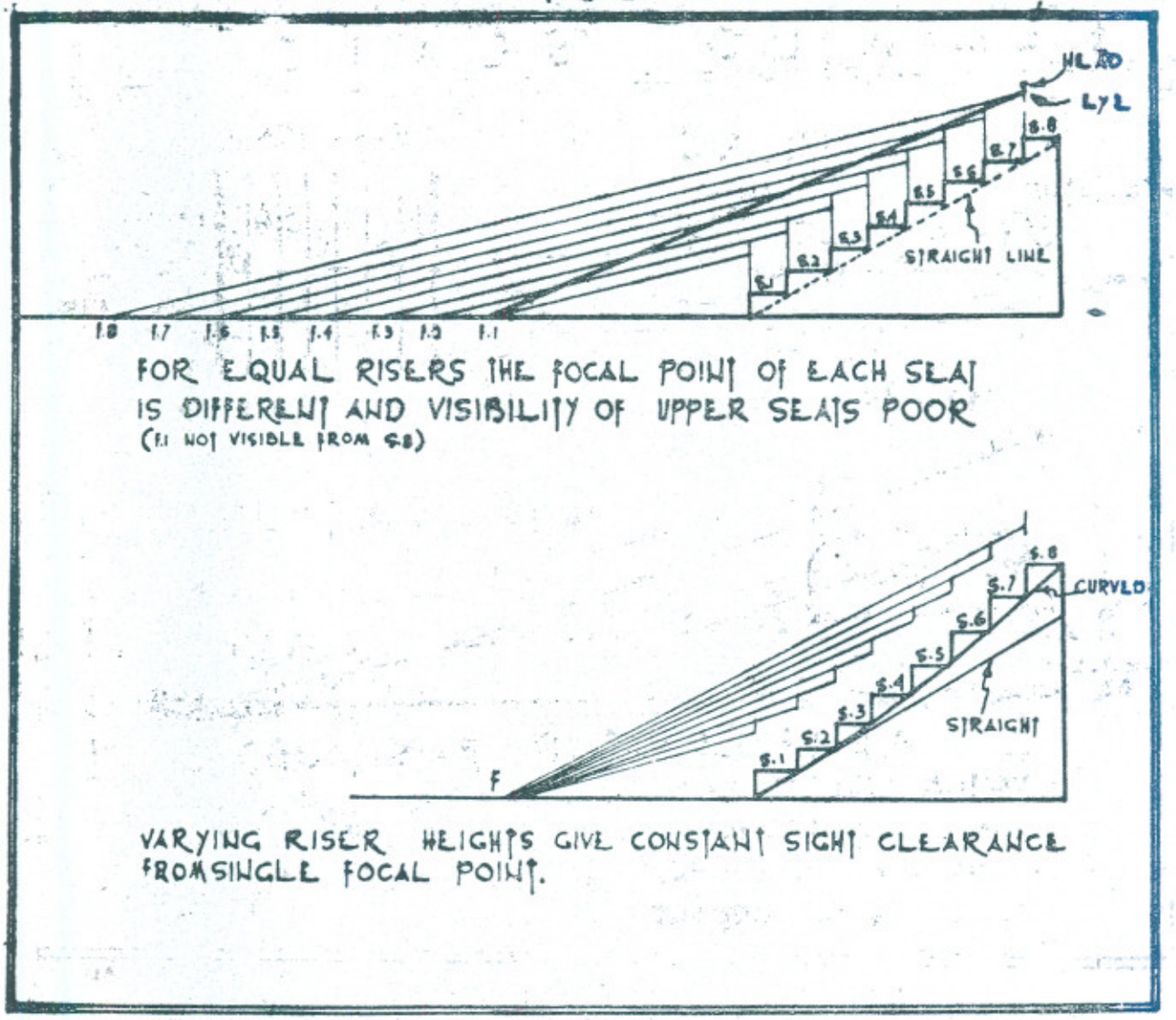
FIG: 14.



appreciably large. For a well laid out and properly proportioned stadium the oblique sight lines will not present any problem. The focal point is the inter section of sight lines with playing field and its establishment is the first step in plotting the sight lines. For foot ball, hockey, tennis and kabbadi this should be taken as the near side of the playing field. For running track a chest height view of the runner in the nearest lane, is satisfactory. In circket there is little activity in the out field near the boundry line and waist height view of the occasional runner will be acceptable. From these starting points the successive rows of seats are located so as to give constant eye clearance (Refer figure 13). This clearance is defined as the distance that the line of sight to the focal point passes above the spectators in the row immediately in front. If the riser height remains constant the clearance progressively becomes less and less towards the rear of the stand. To maintain constant

clearance for sight lines converging from single focal point, the risers are varied in height increasing towards the rear of the stand.

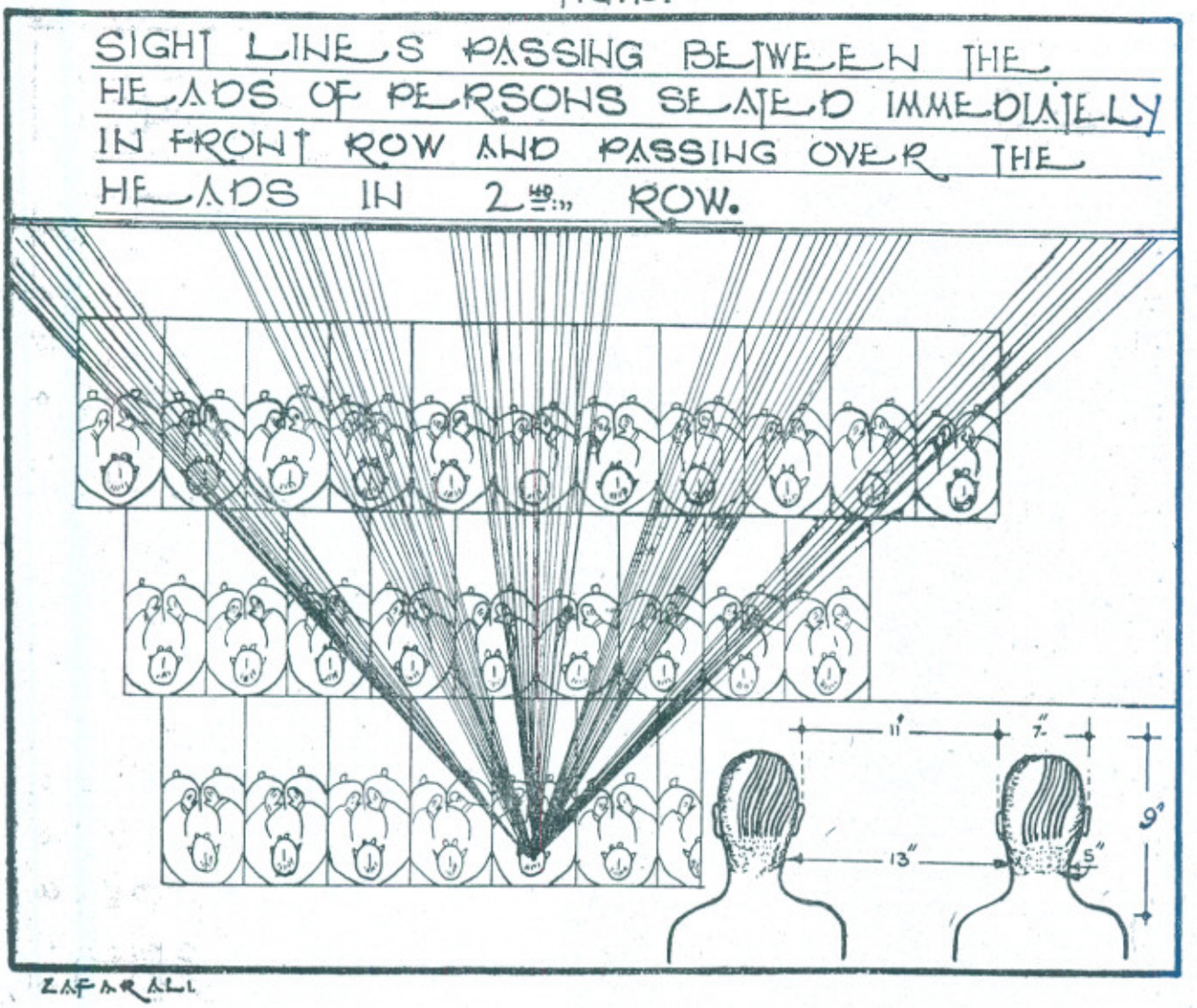
FIG.15.



DRAWN BY- AFZAAL

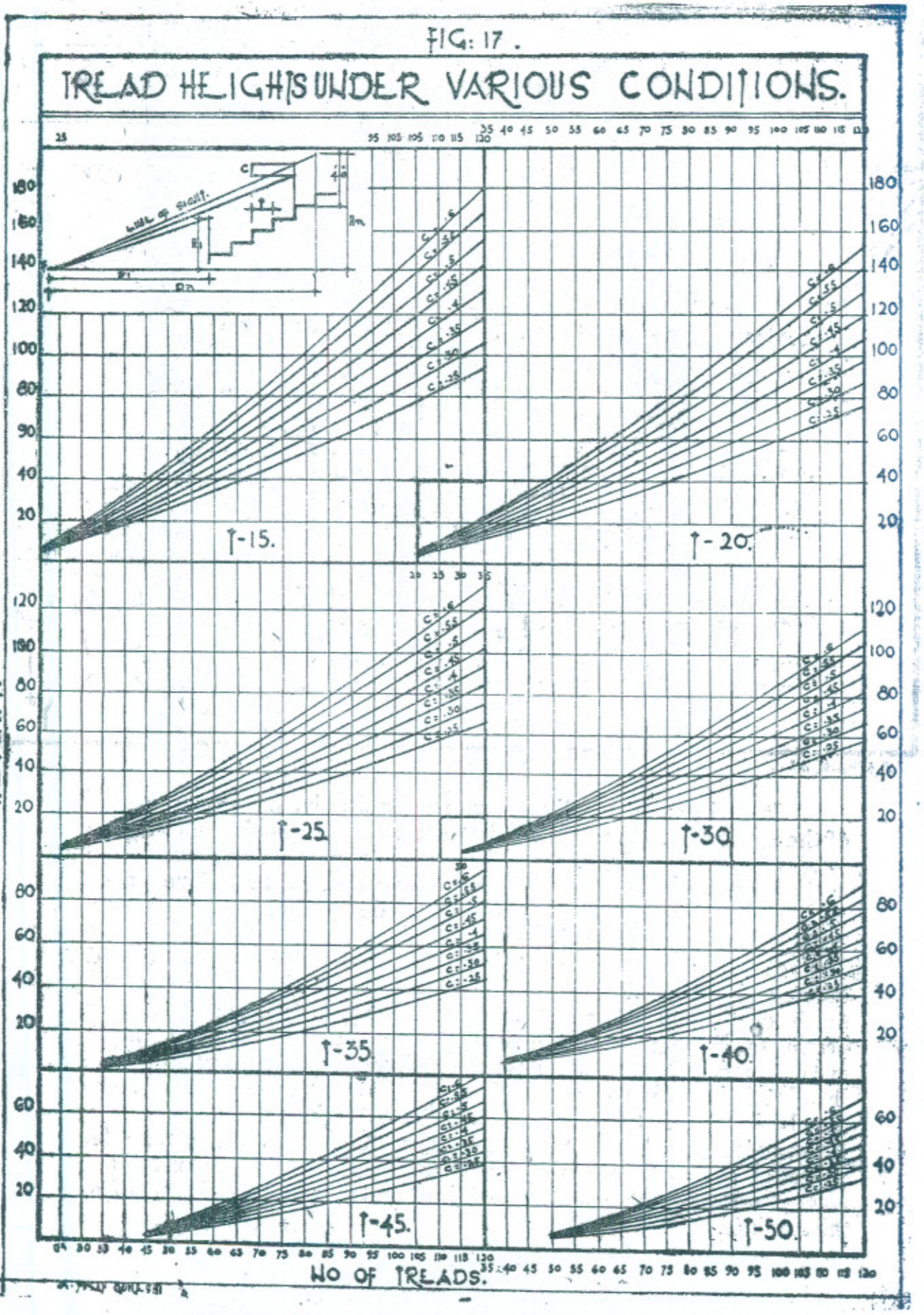
Authorities have differed as to the correct amount of the eye clearance. A seated structure is designed for persons of average size and no normal clearance can prevant the unfortunate case of a small person being seated directly behind large people. In cinemas and theatres the centre of action is reasonably stationery and fairly raised above the front rows. In sports events the focal point of action is rapidly shifting resulting in rapid change in the direction of view. This requires generous provision for sight clearance in comparison to stage or screen performances. Figure No. 18 gives average dimension of a seated person. Some designers have recommended sight clearance of 6 inches while other have adopted 4 to 4½ inches.

FIG. 16.



It has been assumed by many that the site line can pass to one side of the head of the person immediately in front but should pass over the heads of those in the second row. Such assuumption produces stand having less rise with average clearance of about 3 inches. The greater the eye clearance the higher the stadium and longer the climb to seats. A balance between convenience of sight lines and convenience of reaching the seats produces the stadium most satisfactory to the greatest number. The additional cost due to greater height is also a factor. The height of the first seat above the focal point on the playing field effects heights of all other seats as all risers must be increased to maintain the eye clearance. Normally the eye in the front row should not be lower than the heads of persons who might be standing on the ground immediately in front. See figure 35. This places the first eye at an elevation of about 6 ft which in turn places the first foot rest two feet above the playing field. Many stadiums have first row seats placed at a higher level, to provide a more definite barrier seperating the field from the stadium.

FIG: 17.


TREAD HEIGHTS UNDER VARIOUS CONDITIONS.
HEIGHT.
NO OF TREADS.
T-15.
T-20.
T-25.
T-30.
T-35.
T-40.
T-45.
T-50.

Some complicated and labourious formulae have been developed to express the tread height above datam. Large number of variables are involved in determining the tread height and it is best to work out from 1st principles by simple geometrical relationship or graphical plotting as shown in Figure No. 13.

It is possible to simplify the sight line calculations if all horizontal distances are expressed in tread width rather than in feet and modification of formulae and tables by A.B. Randal and E.S. Crossby[4] are given below and graphs vide figure No. 17 give sight line curves for constant sight clearance from focal point with various combination of variables. The graphs are true sight line curves for tread width of 30 inches and only slightly out of scale for other tread widths. The charts cannot be read as closely as may be required for determination of individual riser heights but will be found useful in approximating the height of a proposed stadium under various conditions.

H_n the height of eye above the focal point at the Nth row is given by the equation.

$$H_n = D_n\left(\frac{H_1}{D_1} + C(K_n - K_1)\right)$$

D_n = Distance from focal point to eye in the Nth row in units of established tread width (refer figure 17).

D_1 = Distance from focal point to eye in row 1 in units of established tread width (Refer figure No. 17).

H_1 = Height above focal point to eye in row 1 (Refer figure No. 17). in feet.

C = The sight clearance in feet (Refer figure 17).

T = Tread width. (Refer figure 17).

K_1 and K_n are constants and their values correspouding to D_1 and D_n are given in the following table.

EXAMPLE :—

Determine the height of a stadium 50 rows deep with the first spectator at a distance of 20 rows from the focal point the first eye height 6 ft and a sight clearance of $4\frac{1}{2}''$.

$D_1 = 20$
$D_n = 70$
$H_1 = 6$

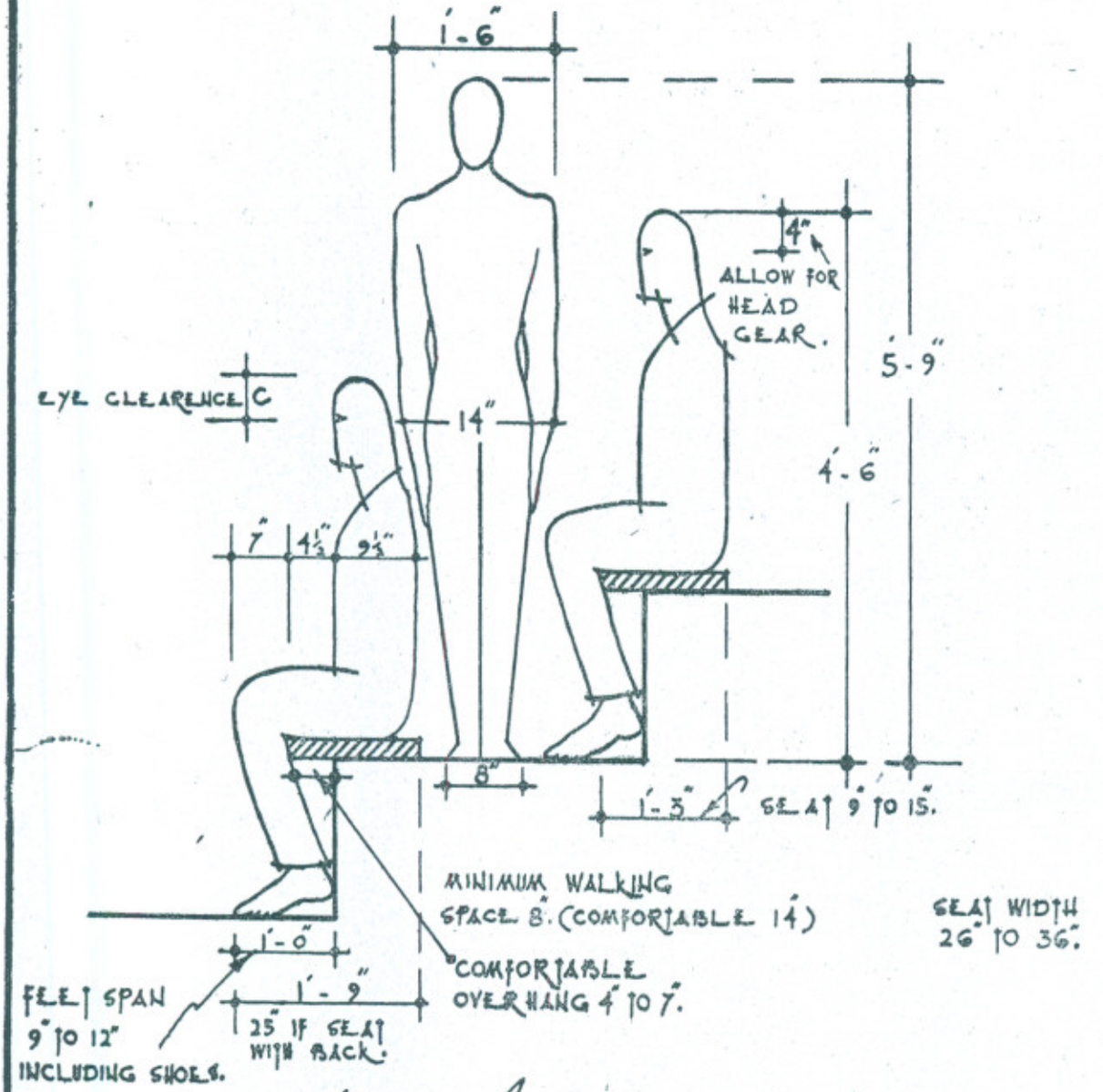
$$C = \frac{4.5}{12} = \frac{3}{8}$$

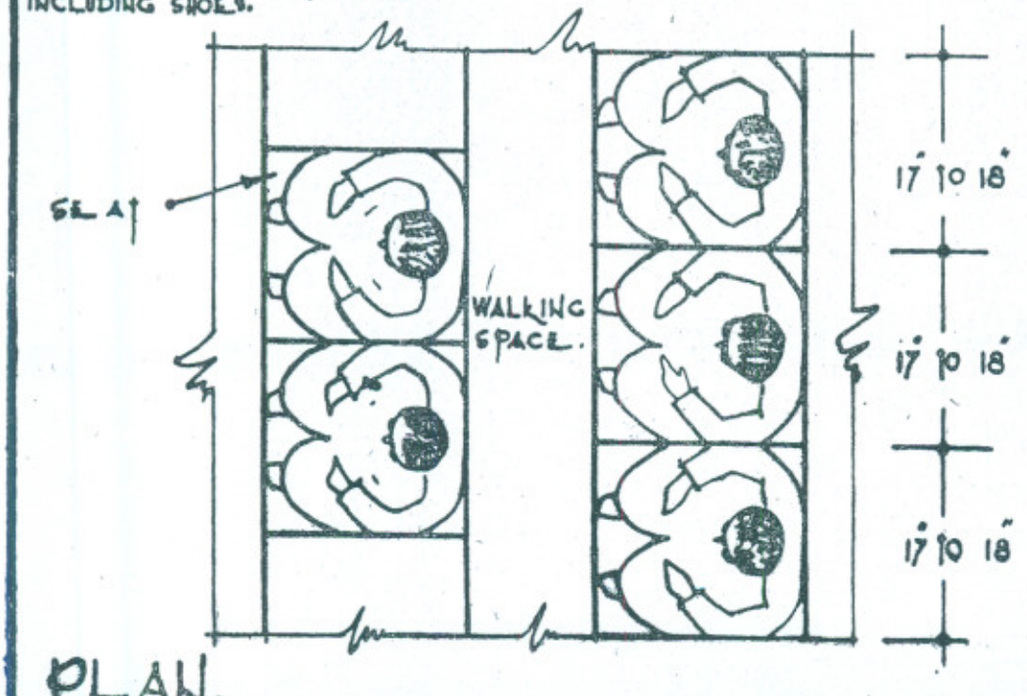
K_1 from chart $= 3.5477$
K_n ,, ,, $= 4.8186$

$$\therefore\ H_n = 70\left(\frac{6}{20} + \frac{3}{8}\,(4.8186 - 3.5477)\right) = 54.34 \text{ ft.}$$

FIG. 18.

MINIMUM SEATING DIMENSION.



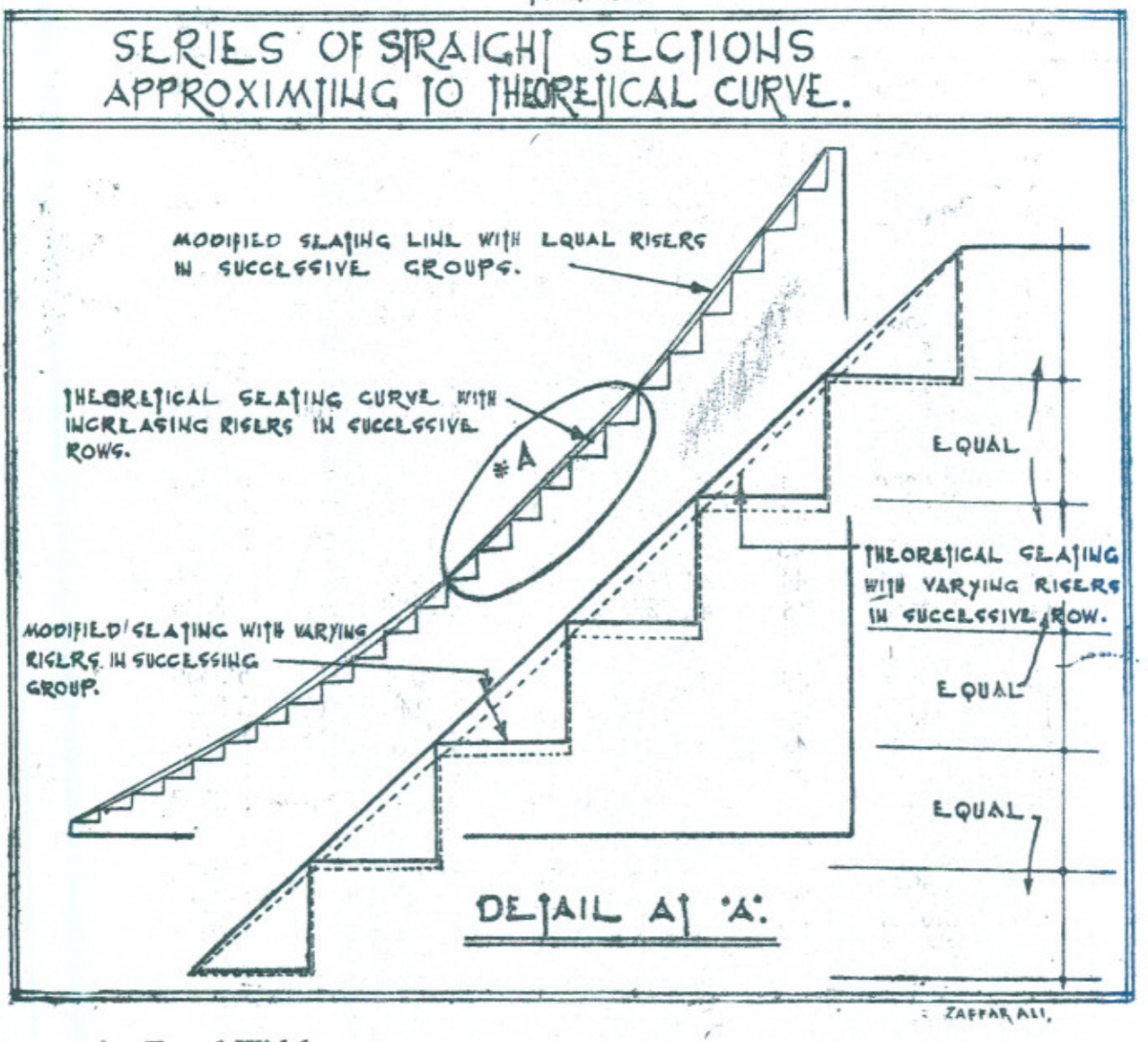


PLAN.

D_n	K_n	D_n	K_n	D_n	K_n	D_n	K_n
1	0·0000	31	3·9950	61	4·6799	91	5·0826
2	1·0000	32	4·0272	62	4·6963	92	5·0936
3	1·5000	33	4·0585	63	4·7124	93	5·1044
4	1·8333	34	4·0888	64	4·7283	94	5·1152
5	2·0833	35	4·1182	65	4·7439	95	5·1258
6	2·2833	36	4·1468	66	4·7593	96	5·1363
7	2·4500	37	4·1746	67	4·7744	97	4·1469
8	2·5929	38	4·2016	68	4·7894	98	5·1571
9	2·7179	39	4·2279	69	4·8041	99	5·1673
10	2·8290	40	4·2535	70	4·8186	100	5·1774
11	2·9290	41	4·2785	71	4·8328	101	5·1874
12	3·0199	42	4·3029	72	4·8469	102	5·1973
13	3·1032	43	4·3267	73	4·8608	103	5·2071
14	3·1801	44	4·3500	74	4·8745	104	5·2168
15	3·2516	45	4·3727	75	4·8880	105	5·2264
16	3·3182	46	4·3949	76	4·9014	106	5·2360
17	3·3807	47	3·4167	77	2·9145	107	5·2454
18	3·4396	48	4·4380	78	4·9275	108	5·2547
19	3·4951	49	4·4588	79	4·9403	109	5·2640
20	3·5447	50	4·4792	80	4·9530	110	5·2732
21	3·5977	51	4·4992	81	4·9655	111	5·2822
22	5·6454	52	4·5188	82	4·9788	112	5·2913
23	3·6908	53	4·5380	83	4·9900	113	5·3002
24	3·7343	54	4·5569	84	5·0021	114	5·3090
25	3·7760	55	4·5754	85	5·0140	115	5·3178
26	3·8160	56	4·5936	86	5·0257	116	5·3265
27	3·8544	57	4·6115	87	5·0374	117	5·3351
28	3·8915	58	4·6290	88	5·0489	118	5·3437
29	3·9272	59	4·6463	89	5·0602	119	5·3521
30	3·9617	60	4·6632	90	5·0715	120	5·3605

Theoretical seating curves require each riser to be slightly higher than the proceeding one and these complicate construction. Adoption of a series of straight sections approximating to the theoretical curve simplifies the construction and is economical. In accordance with the structural gird system or other considerations the riser heights may be varied for succeeding groups of 5 to 10 rows rather than for each row. This close approximation has proved entirely satisfactory.

FIG: 19.



4. Tread Width

The distance between rows commonly called the tread width is a controlling factor for the structure as it affects the convenience, comfort, safety and cost. Determination of tread width depends on.

1. Use of stadium.
2. Type of seats.
3. Seasons of use and climate.

It is expected that the crowds will be seated when the game starts. The spectators will remain in their seats during the actual play and movements will occur at intervals. In cricket it is likely, that there will be more movements in an out of seats during the progress of per-

formance. However in all the games, some movements in and out of seats during the actual play are inevitable and sufficient distance between spectators and seats should be allowed for such passage but too ample space will defeat its own purpose by encourging too frequent passage of vendors and others along the rows to the annoyance of the spectators. Figure No. 18 gives minimum requirements.

Warm weather requires more air space. Colder climate makes close contacts less objectionable. Spacing of rows should be as small as possible for economy but sufficient for comfort and good view. The use of stand, type of seats, weather and economic considerations influence the spacing of rows and varies from 22 inches to 30 inches for seats without backs and 28 inches to 36 inches for seats with backs.

5. Seats

In the design of seating several general considerations are important, the kind of contest or exhibition, comfort, convenience and probable behaviour of spectators. The proper balancing of cost against the comfort and convenience of spectators are often rated as even more important than the interest of the players. With a seat for every one and every one in the seat the likelihood of crowds becoming unmanagable in any period of excitement is reduced to minimum. The space allowed for each seat lengthwise in a row is generally between 11 to 18½ inches. Height of seat from floor should be approximately 14 to 18 inches. The permanent seats are generally constructed of concrete and can be covered with *durries* or coir mattings. Wood tops with or withouts backs are also used. Diagram No. 20 shows typical standard seats. Wood with good resistence to deterioration should be used and preservatives if used should not stain spectators clothing. Seats should be generally numbered and ordinarily should not be carried over expansion joints.

The average seat takes about 3·1 sq ft of floor space. The efficiency of seating arrangement can be gauged as under.

$$\text{Efficiency factor} = \frac{3.1}{\text{G.A.}}$$

where G.A. is gross area per seat i e. the total plinth area including seats, passages etcetra divided by the planned capacity of the number of spectators.

6. Shape.

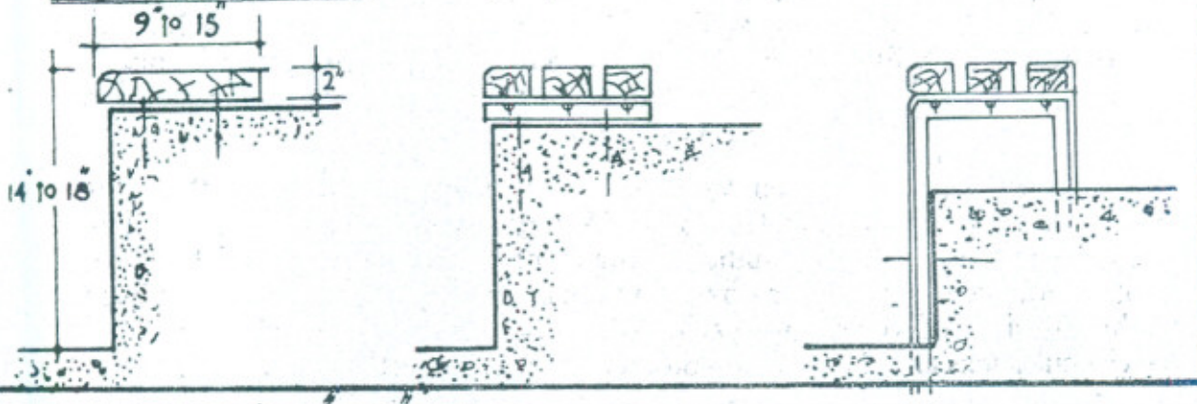
The shape of the stadium depends on (a) The sports and the range of other activities for which it is designed (b) Topography and orientation of the playing field (c) The desire and practicability of providing the best accommodation at locations of greatest spectators interest.

For Tennis and volley ball the seats opposite the net are close to the play but least desirable. Constant turning of the head and eyes to

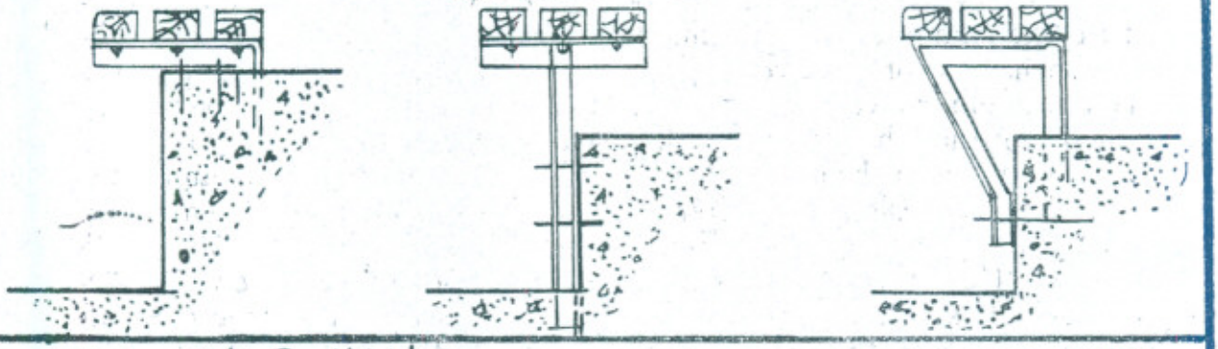
FIG. 20.

TYPICAL STADIUM SEATING.

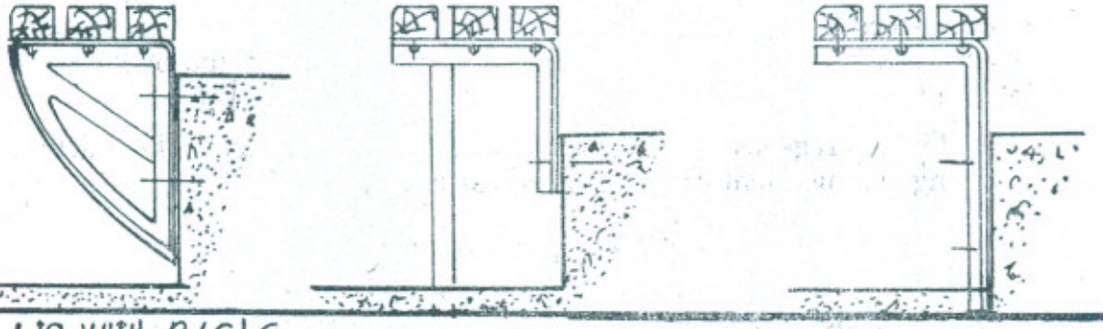
NO OVER HANG. UNCOMFORTABLE & WASTEFULL IN SPACE



OVER HANG 4" to 7". COMFORTABLE PROVIDE ADDITIONAL LEG SPACE & ECONOMICAL



FULL OVER HANG. NO ADDITIONAL COMFORT FIXING COMPLICATED



SEATS WITH BACKS REQUIRE WIDER TREADS