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Design of Pervious Pavement by Using Interlocking Cement Concrete Blocks

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ABSTRACT

Permeable pavements typically consist of pervious concrete, porous asphalt, permeable interlocking concrete paving units or grid type systems over an open-graded base/sub base layer(s). Permeable pavements infiltrate storm water, reduce peak flows, filter and clean contaminants and promote groundwater recharge. They have gained substantial popularity in North America and have become an integral part of low impact design and best management practices for storm water management. In order to be effective, permeable pavement must be designed to provide sufficient structural capacity to accommodate the anticipated vehicle loadings, manage storm water flowing into the surface and soil sub grade, as well water draining out of the base/sub base.

While there are many well-designed and constructed permeable pavements, they are a relatively new technology with some projects performing below design expectations. This paper describes some essential best practices for permeable pavement design and construction, and focuses on lessons learned from case studies of permeable pavement construction in North America. Included are driveways, parking areas, roadways, roadways shoulders, walkways and unusual uses of permeable pavements subjected to heavy loadings including buses and even military tanks.

INTRODUCTION

PERVIOUS PAVEMENT:

Any pavement which allows the water through it or which takes and seeps water through it to the bottom is called as pervious pavement.

- Permeablepavementsworkbycontrollingthereleaseofsurfacewatertothenaturalenvironment. This is achieved by the technique is known as attenuation
- Attenuation means slowing down or braking
- The surface water is collected by the pavement and held in storage and then it is slowly released into atmosphere in a controlled manner to minimizing the risk of flooding or inundation
- Sand filters in that they filter the water by forcing it to pass through different layers which are laid by different sizes of aggregate.
- So in permeable pavement most of the water seeped through mechanical process. As precipitation falls on the pavement water seeps to the storage basin where it slowly releases to the surrounding soil.
- Pervious pavements are constructed with porous as halt, porous concrete, concrete or brick pavers, open celled pavers etc...
- Depending on the design, paving material, soil type and rainfall, permeable pavements can infiltrate70%to 80% of annual rain fall.
- Permeable pavements designed for moderately heavy loads.
- Concrete block pavers having the highest load bearing capacities followed by porous as halt and porous concrete and then plastic grid pavers.

So here we have chosen that the design of pervious pavement by interlocking cement concrete blocks

SCOPE:

InterlockingConcreteBlockPavementshavebeenextensivelyusedinanumberofcountriesforquitesometime.Consi

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deringtheiradvantagesandpotentialforuse,theguidelines havebeenpreparedforthedesignandconstructionofsuchp avements,givingthesuggestedapplications,designcatalo gues,constructionpracticesandspecificationsfortheiruse .

APPLICATIONS

InterlockingConcreteBlockPavementshave been found to have applications in severalsituations.Suchas:

1. Footpathsand Side-walks
2. CycleTracks
3. Residential streets
4. Car Parks
5. Fuel Stations
6. RuralRoadsthroughvillages
7. HighwayRestAreas
8. Toll Plaza
9. BusDepots
10. Approaches to RailwayLevelCrossings
11. Intersections
12. CityStreets
13. Truck Parking Areas
14. Industrial floors
15. UrbanSections of Highways
16. RoadRepairs during Monsoon
17. ContainerDepots
18. Port Wharf and Roads
19. Roads in high altitude areas

ADVANTAGES AND LIMITATIONS OF INTERLOCKINGCONCRETE BLOCKPAVEMENTS.

ADVANTAGES

(i) Since the blocks are prepared in the factory, theyareof averyhighquality, thus avoiding the difficulties encountered in quality control in the field.

(ii) Concrete block pavements restrict the speedofvehicles to about 60 kmperhour, whichis an advantage incitystreets and intersections

(iii) Because of the rough surface, thesepavementsareskid-resistant.

(iv) The block pavements are ideal for intersections where speeds have to be restrictedandcorneringstresses are high.

(v) Thediggingandreinstatement of trenches for repairs to utilities is easier in the case ofBlockpavement.

(vi) These pavements are unaffectedbythe spillage of oil fromvehicles, and are ideal forbs stops, bus depots and parking areas.

(vii) They are preferred in heavily loaded areas like container depots and ports astheycanbe very well designed to withstand the highstressesinducedthere.

(viii) In India, thelayingof concrete block pavements can beachievedat allow costbecauseofthe availability of cheap labor.

(ix) Cue the concrete blocks aregreyin color, theyreflectlight better then the blackBituminouspavements, thus bringing down the cost of street lighting.

(x) The cost of maintenance is much lower than bituminous surface.

(xi) Block pavement does not need in-situ curing and so can be opened to traffic soonaftercompletion of construction.

(xii) Construction of block pavement is simple andlabour-intensive, andcan bedoneusing simple compaction equipment.

(xiii) Maintenance of block pavement is simple and easy. Also, the need for frequency of maintenance is lowascompared to bituminous pavement.

(xiv) Structurallyroundblocks can be recycled many times over.

(xv) Unlike concrete pavements, blockpavementdoes not exhibit verydeterioratoryeffectdue to thermal expansion and contraction, and arefreefrom thecrackingphenomenon.

(xvi) Use of permeable block pavement in cities and towns can help replenish depleting underground sources of water, filterpollutants before theyreachopenwatersources, helpreduce storm water runoff and decrease the quantum of drainage structures.

LIMITATIONS

(I) Concrete block pavements cannot be used for high speed facilities.

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(ii) The ridingqualityis reasonably good for low-speed traffic, but is inferior to thatobservedon a machine laid bituminous or concrete pavement.

(iii) Thenoisegeneratedis high, 5-8 dB, higher than bituminous surfaces.

(iv) A very goodattentiontopavementdrainageisneededbecausethe water canseethroughthe joints.

TYPESAND SHAPESOF BLOCKS

The blocks cane interlockinghorizontallyandvertically, (I) is the shape which was intended for imitating the stone set blocks.

(ii) Is unimproved version with manydentated facesforbetter contact between adjoining blocks thus enhancing the interlockingeffectandfrictionbetween them. This helps inincreasingthe shearstrengthof the block system and thus the load dispersal capacity.

Theoveralldimension of blocks used in various parts of the worldrangesasunder:

- (Mean length/mean width) should not belles than 1 and should not be more than 3
- Length/Thickness :>4

Inadditiontoregular blocksdescribedabove, supplementaryblocksofhalfsizewouldberequiredforpavingpurpose.Inthecaseofrectangularblocks, morenumberofhalfblockswouldbegenerallyrequired than othercategoryofblocks.

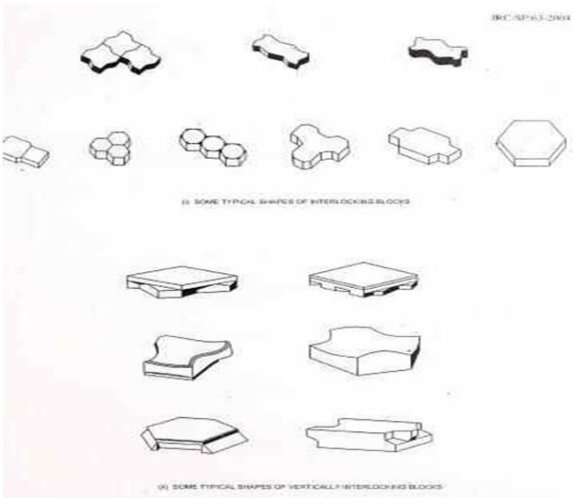
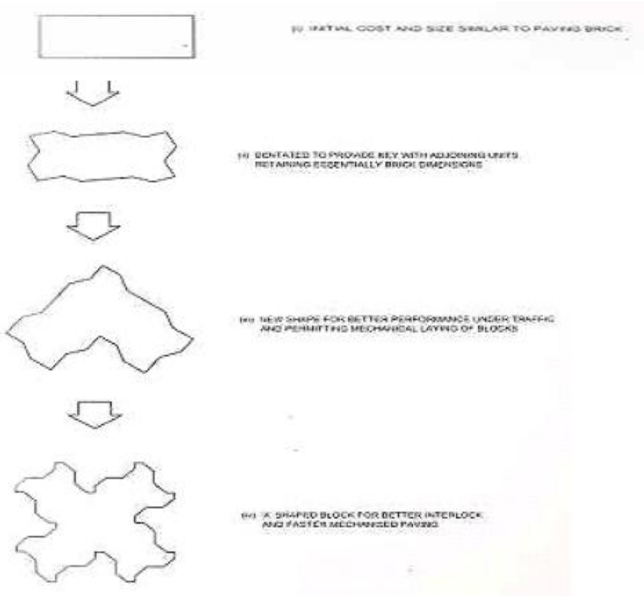
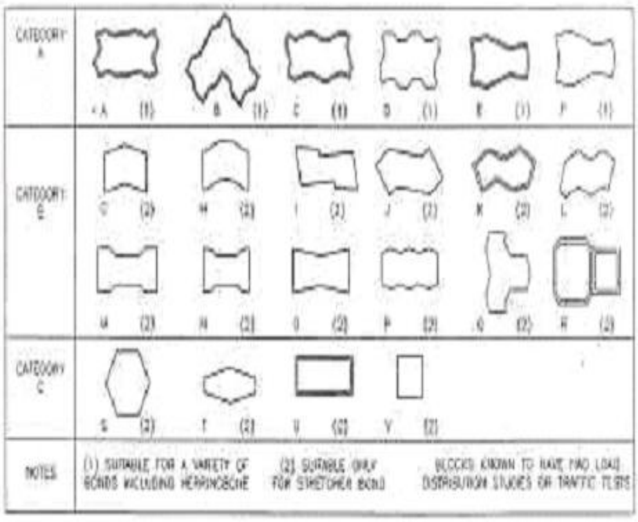


Fig. 1. Some shapes of interlocking blocks





SPECIALGRASS BLOCKS:

Forimprovingaestheticlooksofpavedareas, architectshavebeenmakinguseofblockpavementextensively.Thenumerouspavingblocksandtheirjointsmellowdowntheharshnesscreated by large transverse joints formed in conventional concrete pavement.

For improvingaestheticsfurther, grassblocks have been developed. Thesewhenconstructedin a grid formation allow space in the pavement for growing grasses shown. These are best suited forwalkways, driveways, etc. Colored blocks also add to theaestheticbeauty

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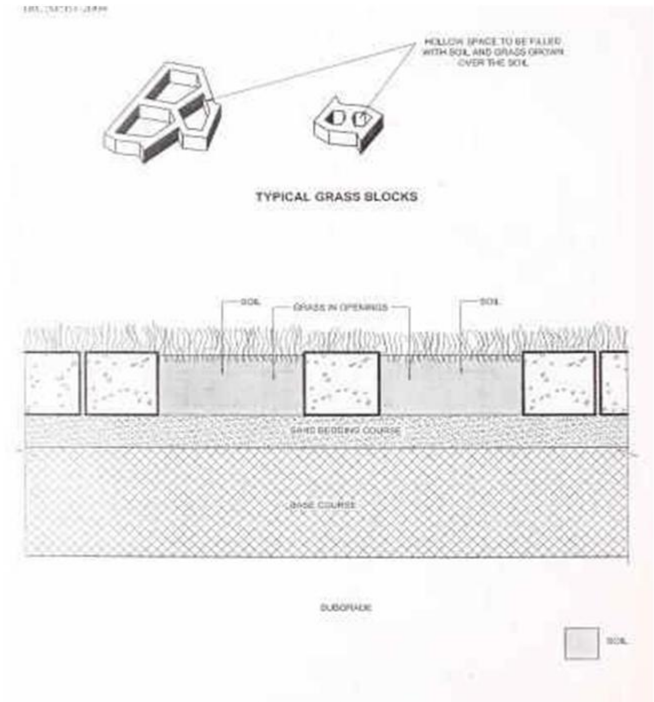

Fig. 4. Grass blocks and the construction technique

LITERATUREREVIEW

Theliteraturereviewresultedinexperimentsaroundtheworldmainlyinthelaboratoryoronsiteexperimentalsetups (seeaviewonanexperimentbytheUniversityofAbertay. Most of the results had highinfiltrationrates, higher than what is determined on site.Sincespecificfactorsarehardtosimulate (e.gcloggingduetoatmosphericdepositionandleaves) the main focus of this research was on inset monitoring. Permeablepavementbyusinginterlockingcementconcreteblocksislaid3500yearsagoinNorthAmerica.Theyhavenoclearknowledgeatthattimehowitworks.AfterthatNorwayinHudsonvalleytheyhavelaidandtestedtheinfiltrationrates.Bytheseliteraturereviewswe said that doubleringinfiltrometers are best suited forcheckinginfiltration rates. Thesearelaidandexperimentallysucceedinsomanycountrieslikeu.k,Netherlands,Englandetc....bytheallthestudy oftheseliteraturereviewswehavesaidthattheseareusedforlowspeedroadsandwherethegroundwaterrechargeisrequiredandthesearelongdurableandreplacementforotherparkingareasandwalkwaysispossiblewhentheremovalofblocks takes place after thedesignperiod of road.

Sofromalltheseihavebeentakenasadesignofperviouspavementbyusinginterlockingcementconcreteblocksinruralareasasconnectedroadsfromasmallcitytovillage.Inthese ihavejustdesignedthevariouslayersandsizesoftheblocks aspercodalspecifications.

COMPOSITION OFBLOCKPAVEMENT

Exceptforthetopwearingpartofthepavement, thebaseandsub-baselayersaresimilartotheconventionalflexibleorrigidpavement.Dependinguponttheloadcomingonthem, the composition of the pavement differs.

Block Thickness

Interlockingconcreteblockscomeindifferentthicknesses.Theseblocksserveaswearingsurfacebutatthesametimehelpinreducingthestressesimposedonsubgradeandalsohelpinresistingpavementdeformationandelasticdeflections similartothebasecourseofaflexible pavement. ForCategory'A'blocksusedforlighttraffic,suchas,pedestrians,motorcars,cycles,etc.,ablockthicknessof60mmisadequate;formediumtraffic,athicknessof80mmisgenerallyused;for heavily traffickedroads,Category'B'blocksofthethickness100-120mmareused.Thickblocksarebestsuitedwherehighvolumesofturningmovementsareinvolved.

Non-uniformityinthicknessofblocksaffectstheevennessofthe surface.Ablockpavementwhichisinitiallypavedtoalevelledsurfacewillsettleunevenlywiththemovementofvehicles.Inviewofthis,allblocksshouldbeofthesamethickness, withmaximumallowabletolerancelimitsof±3mm.Similarly,variationsinlengthandwidthofblocksshouldbelimitedto±2to3mmforensuringuniformjointwidthandavoiding staggeringeffect.

SAND BEDDINGAND JOINTING

Alayerofsandbeddingisprovidedbetweenblockpavementandbase/sub-baseforthefollowing Reasons:

(I) to provide a cushion between the hard baseband the paving blocks

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(ii) The base orsub-basewill has some permitted surface unevenness.ByprovidingaLayer of sand bed, the paved blockcanbe levelledperfectly.
(iii) The sand bed acts as a barrier and does not allow propagation ofcracksformed in base/Sub-base.
(iv) Thesandalso helps to keep lower part ofthejoint filled with sandandprovidesaddedInterlockingeffect.

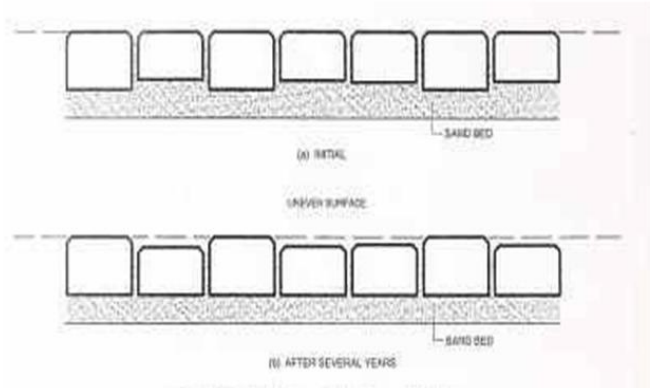

Fig. 7. Effect of thickness variations in paving blocks

Thesandbedshouldnotbetoothicklestitwouldbedifficulttocontrolthesurfaceleveloftheblocks.Alayerthicknessof 20to40mmisfoundtobesatisfactory.Forblockpavementtoperformsatisfactorily,itisnecessarythatthelowerlayersareprofiledtoproperlevelandfinishandthatthebeddingsandlayerisofuniformthickness.Varyingthicknessofsandbedultimatelyresultsinunevensurfaceofthepavement.Thegradingandqualityofsandisveryimportantfortheblockpavementtoperformsatisfactorily.Thesandusedshouldbefreefromplasticclayandshouldbeangulartype.Itshouldnotbeofdegradabletypefore.g.,sandproducedfromlimestone,etc.islikelytogetpowderedundertheloading.Jointsbetweenblocksarefilledbyfinesand.Normally,thebottom20to 30mmofthejointgetsfilledwithbeddingsand,whereas,theremainderspacehastobefilledwithjointingsandbybroomingit from the top.Thejoints are normally2 to 4 mm wide.

EDGERESTRAINTBLOCKSAND KERBS

Concreteblocksontraffickedpavementstendtomovesidewaysandforwardduetobrakingandmanoeuvringofvehicles.Thetendencytomovesidewayshastobecounteractedattheedgesbyspecialedgeblocksandkerbs.Theedgeblocksshouldbedesignedsuchthattherotationordisplacementofblocksisresisted.Thesearetobemadeofconcreteofhighstrengthtowithstandthetrafficwheelloadingwithoutgetting damaged.Thesemembersshouldbemanufacturedorconstructedin-situtohaveatleasta28daycompressivestrengthof30MPaorflexuralstrengthof3.8MPa.Asfaraspossibletheedgeblocksshouldhaveverticalface towards the inside blocks.

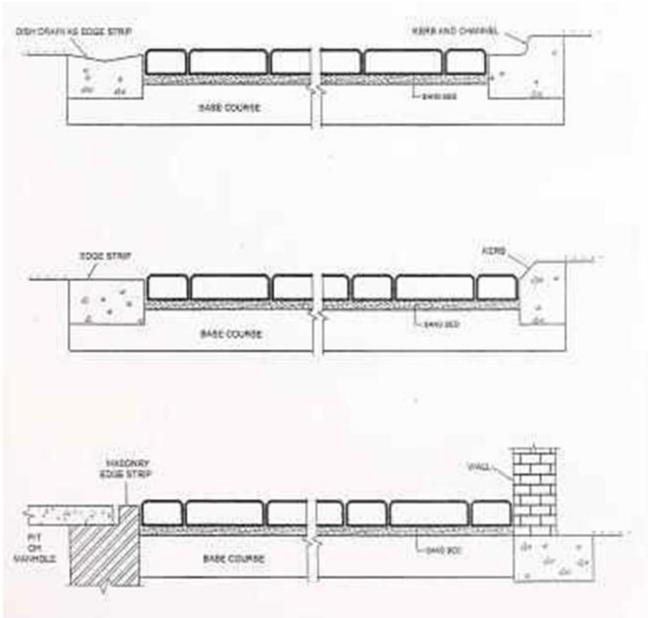

Fig. 8. Edge restraints

STRUCTURAL DESIGN OF CONCRETE BLOCK PAVEMENT

THICKNESS TABLE FOR ICBP

Traffic and road type	Subgrade C.B.R		
		Above10%	5%-10%
• Cycletracksand pedestrianfootpaths	Blocks	60	60
	Sandbed	20-30	20-30
	Base	200	200
• Commercialtraffic axle load repetitionslessthan 10 msa	Blocks	60-80	60-80
	Sandbed	20-40	20-40
	Basecourse	250	250
• Residentialstreets	Sub base course	200	250
• Commercialtraffic axle load repetitions 10-20msa	Blocks	80-100	80-100
	Sandbed	20-40	20-40
• Collectorstreets, industrial streets ,bus andtruck parkingareas	Basecourse	250	250
	Sub base course	200	250
• Commercialtraffic axle load repetitions 20-50 msa	Blocks	80-100	80-100
	Sandbed	20-40	20-40
	WBM/WMM baseor	250	250
• Arterialstreets	WBM/WMMbase	150	150
	And DLCcover it	75	75
	Granularsub base	200	250

1 Thickness of layersgivenabove is in mm.
2 Granular sub-bases should haveatleast 150 mmlayerat the bottom which is drainable.
3. If thesubgrade soil has a CBR of less than 5, it should be improvedbysuitableStabilisationtechnique to bring the CBR value to 5.
4. Mesa denotes repetitions in million standard axles
*Incase of roads having inadequate drainage or heavyrainfallareas (above1500 mmperannum)

MANUFACTURE OF PAVING BLOCKS

Themethodofmanufactureofpavingblockshasanimportantbearingonthequality,durabilityandleveloffinish-dimensionaltolerance,etc.allofwhichreflectontheultimateperformanceoftheblockpavementduringservice.Attheveryoutset,therefore,itistobeemphasizedthathand-castedconcreteblocksareunacceptableforuseandthatanappropriateplantshouldbeusedwhichwouldmakeitpossibletoapplyhighpressuretogetherwithcontrolledvibration.

Adaptationofproductionfacilitiesdesignedforhighqualityhollowmasonryblocks,thoughfeasible,isnotaseconomicalandasefficientastheuseofpurposedesignedmachineryforpavingblockmanufacture.Essentially,themanufacturingprocessinvolvescompactingconcrete,inasteelmouldclampedtoavibratingtable,byhydraulicpressure.Concreteisfedintothemouldfromahopperbyadrawer-ifasecondhopperisadded,ablockcanbemadeoftwokindsofconcretehaving"backing"and"facing"surfaces.Inthe"facing"oftheblock,thetop5mmhasgreateramountsofcementandsandtomakeitmoredurableandskidresistant,andextrapigmentisaddedforthecolouredfacevis-a-istherestoftheblock.Inthefirststageofcompaction,pre-vibrationiseffectedbyrunningthevibratorsattachedtothevibratorytable,thefrequencygenerallybeingintherangeof50to100Hz.Inthesecondstageofcompaction,compressionpressureisappliedtothetamperheads,alsofittedwithvibratorsforahighlevelofsurfacefinish.Blocksareextrudedfrommouldbyforcingdownthetamperheads,afterthevibratingtableisdisengagedfromthemould.Theblocksthusprepparedarestackedeitherinasinglelayerormultiplelayersforcuring, depending on the plant usedbeingsinglelayeror multi-layer.

LAYING OFBLOCKS

Blockscanbelaidgenerallybymanuallabourbutmechanicalaidslikehand-pushedtrolleys can expeditethework. Normally, lying should commence from theedgestrip and proceed towards the innerside.When dentate blocks aroused, the laying done at two fronts will create problem formatchingjoints inthemiddle.Hence,asfaraspossible,layingshouldproceedinonedirectiononly,alongthe entire Width of the area to be paved.

While locating the starting line, the following should be considered:

- Onaslopingsite, start from the lowest point and proceed uphill on continuous basis, to avoid downhill creep in incomplete areas.
- In case of irregular shaped edge restraints or strip, it is better to start from straight
- Influence ofalignmentof edge restraints on achieving and maintaininglayingbond.

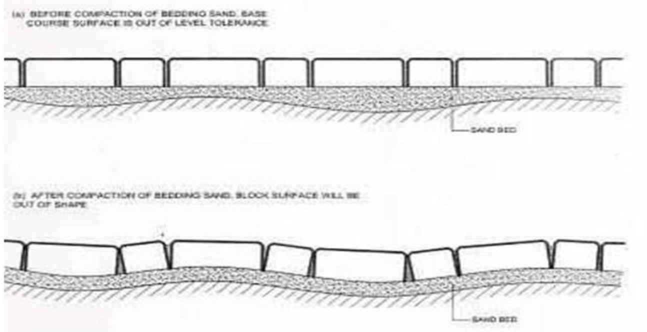

Fig. 12. Effect of base-course surface shape on bedding sand and block surface shape

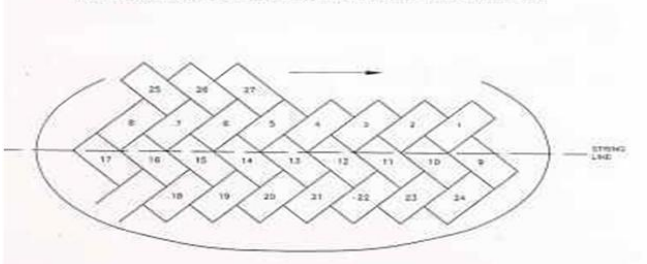

Fig. 13. Starting at irregular shaped edge restraint

MECHANISEDMETHODS:

Mechanisedlayingrequirestheuseofspecialised equipment fortransportingandplacingclustersofpavingblocks.Thesizeofpavingblockclustersuitableforpaving,isusually0.3to0.5m-inareaforhand-

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operatedequipment;forfullymechanisedequipment,theclustersurfaceareacanbeuptoabout1.2m-.Theseclustersaredesigned to maintain joint space of about 3 mmbetween blocks, when clamped togetherSincethe blocks are placed in separate clusters, there exists the possibility of damage if jointsBetweenadjacentclustersrununinterruptedthroughoutthepavement.Toovercomethisproblem,clustersmaybearrangedsothatthejointsareperiodically staggeredbothalong andacrosstheclusteraxisorlinkblocksareinstalledbyhandacrossthesejointsMechanisedlayingmustbecoordinatedwiththemanufacturer,sothattheblocksaredeliveredstackedonpalletsintherequiredpattern;insomecases,spacingribsmaybecastonthesidesofblocksto preserve the required joint spacing's.

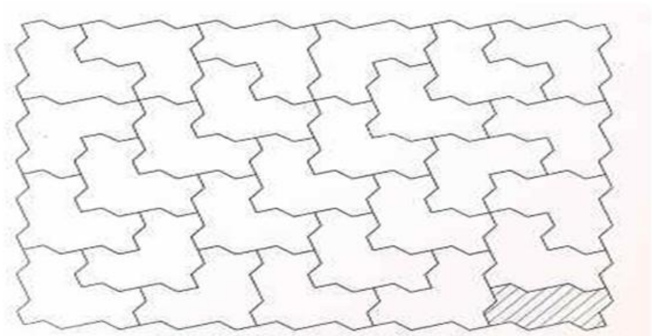

Fig. 16. Typical block cluster in mechanised laying

COMPACTION:

Forcompactionofthebeddingsandandtheblockslaidoverit,vibratoryplatecompactors are usedoverthelaidpavingunits;atleasttwopassesofthevibratoryplatecompactorareneeded.Suchvibratorycompactionshouldbecontinuedtillthetopofeachpavingblockislevelwithitsadjacentblocks.Itisnotgoodpracticetoleavecompactiontillendoftheday,assomeblocksmaymoveunderconstructiontraffic,resultinginthewideningofjointsandcomercontactofblocks,whichmaycausespallingorcrackingofblocks.Thereshouldbe minimaldelayincompactionafterlayingofthepavingblockstoachieveuniformityofcompactionandretentionofthepatternhowever,compactionshouldnotproceedcloserthan 1 m from the laying face,exceptafterof the pavement. Duringvibratorycompactionofthelaidblocks,someamountofbeddingsandwillworkitswayintothejointsbetweenthem;theextentofsandgettingworkedupintothejointswilldependonthedegreeofpre-compactionofsandandtheforceappliedbytheblockcompactor.Standardcompactorsmayhaveaweightofabout90kg,plateareaofabout0.3m-andapplyacentrifugalforceofabout15kN,whileheavydutycompactorsmayweigh300-600kg,haveaplateareaofabout0.5-0.6m-andapplyacentrifugalforceof30-65kN.Wherethebeddingsandhasbeenpre-compactedandforheavilytraffickedblockpavements,heavydutycompactorsshouldbeused.Aftercompactionbyvibratoryplatecompactors,some2to6passesofavibratoryroller(withrubbercoateddrumsorthoseofstaticweightlessthan4tonnesandnominalamplitudeofnotmorethan0.6mm) willfurtherhelpincompaction ofbeddingsand and joint filling

JOINTFILLING:

Theimportanceofcompletejoint fillingcannotbeover-emphasised. Unfilledorpartiallyfilledjointsallowblockstodeflect,leadingtolooseblocks,possiblyspallingtheedgesandalocallydisturbingbeddingsandlayer,Afterthecompactionofthebeddingsandhasbeencompleted(andsomebeddingsandhas-beenforcedupinthejointsbetweenblocks),thejointsshouldbecompletelyfilledwithsandmeetingthedesiredspecifications,asgiveninSection6.Thejointfilingsandshouldbestockpiledatsuitablelocationsfor convenience. There shouldbeminimumdelayinjointfilling;theprocessshould in anycase,becompletedbytheendoftheday'sworkThe operationofjoint fillingcomprisesofspreadingathinlayerofthejointfillingsandontheblocksurfaceandworkingthesandintoeachjointbybrooming.Followingthis,afarpassesofheavyplatecompactorareappliedtofacilitatefinesandtofillthejoints. Thesandshouldbebroomedorspreadoverthesurfacewithasmallsurcharge.Drysandanddryblocksarebestforthefillingofjoint,asdampsandtendstostickattheverytopofthejoints;also,iftheblocksarewetandthesanddry,thesandwillagainstickatthejointtop.Hence,ifeithertheblocksorsandarewet,onemaygetafalseimpressionofthejointsbeingfull,butthenextrainwillrevealthattheyareactuallyhollow.Ifthew

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eatherdoesnotallowsandandblockstobedry,thejointfillingsandshouldbewashedinbylightsprinklingofwater.Inthiscase,severalcyclesofapplicationofsand,water-sprinkling and plate compaction will benecessarytocompletelyfillthe joints

OPENINGTOTRAFFIC:

Untilallthejointsarecompletelyfilled,notrafficshouldbepermittedovertheblockpavement.Incaseoflimeorcementtreatedlayersinthepavement,itmustbeensuredthatthesearegivenatleast14and7daysrespectivelytocure,beforetrafficispermitted.Theblockpavementshouldbeinspectedfrequently,toensurethatanyincompletelyfilledjoints,exposedbytrafficand/orweatherarepromptlyfilled.Suchfrequentinspectionshouldbecontinuedtilldustanddetritusfrom theroadwaytightensthesurface of the joints

LAYINGANDSURFACETOLERANCES:

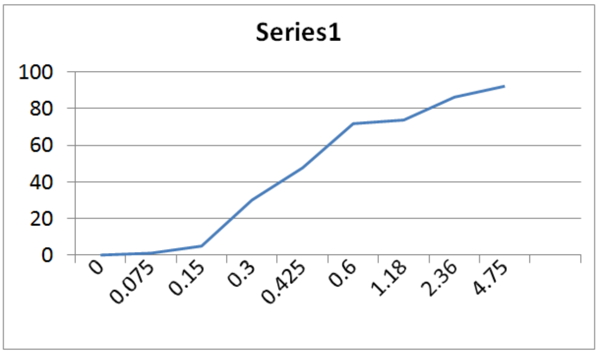
Whilethelaying, thesurfacetolerances, given below Maybe observed:

Layer/Item	Tolerance
• Sub grade	• +0,-25mmof dominated level
• Selectsubgrade/subbase	• +0,-25mmof nominated level
• Base course	• -0,+10mmof nominated level10mmdeviation from a3mstraightedge
•	
PlandeviationFro many3mlineFrom any10mline	• 10mm(maximum) • 20mm(maximum)
• Vertical deviation from3m line atkerbs	• +3mm,-0mm
Intrusions,channels,edgerestraintselsewhere	
• Maximumdifference in surfacelevelbetween adjacent paving units	• +10mm,-15mm • +10mm,-15mm
• Deviation offinished surfacelevelfromdesignated level	• 2mmto4mm
• Jointwidth range	• 10%maxalong 10mline
• Percentageof jointsoutsiderange	• 3mm
• Nominaljointwidth	

RESULTS OF SIEVEANALYSIS:

Sizeofsieve	Weigt ofretainedparticles(gm)	%weight retained	Cummulative % weightretained	%finer
4.75 mm	77	7.7	7.7	92.3
2.36 mm	60	6.0	13.7	86.3
1.18 mm	125	12.5	26.2	73.8
600µ	20	2.0	28.2	71.8
425µ	241	24.1	52.3	47.7
300µ	176	17.6	69.9	30.1
150µ	252	25.2	95.1	4.9
75µ	39	3.9	99	1
pan	10	1.0	100	0

Graph between % passing and sieve sizes



Sieve sizes

RESULTS OFIS LIGHTCOMPACTION TEST

Observations and calculation	sample1	Sample 2	Sample 3	Sample 4
Amount of soil taken (gm)	3000	3000	3000	3000
Amount of water %	6	8	10	12
Weight of emptymould w_1 (gm)	4460	4460	4460	4460
Weightof mould+compactedsoilw_2(gm)	6413	6438	6650	6543
Weightofcompactedsoil$w_3=w_2-w_1$	1953	1978	2190	2083
Bulk density□= w_3/v	1.989	2.014	2.230	2.121
Drydensity□$_d$=□/(1+w)	1.8	1.87	12.02	1.893

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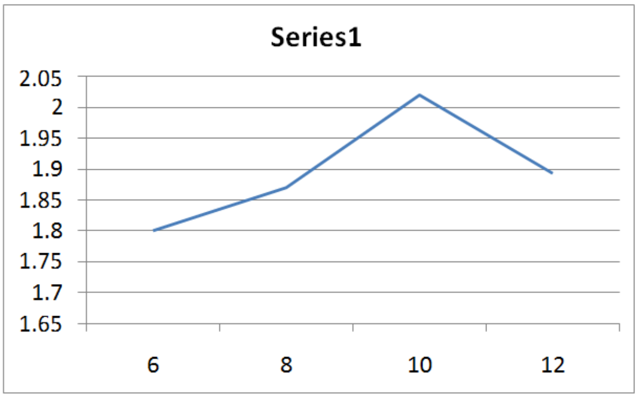
Graph between water content and dry density:



From the graph we can say that the optimum moisture contents 10%.because the maximum drydensityoccurs at that water content.

CONCLUSIONS:

1. Finally we conclude that this aregoodinsteadof c.c.roads in congestedareasbecauseit does not require additional drains
2. Forlowspeedroadsthesearegoodbecauseitisrechargesgroundwaterthenthesurroundinggroundwatertable is rises
3. Theseroadspreventthedustnuisancelikeitcapturesthedustparticlesinthatwayindirectlyit is controlling air pollution
4. Reusability is possible because economical
5. Inparkingareasinsteadofimperviouspavementstheseare preferablebecauseitcangivequickrun offresultinggood when compare to other pavements

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