第 48 卷第 12 期
2021 年 12 月

湖南大学学报（自然科学版）
Journal of Hunan University（Natural Sciences）

Vol. 48. No. 12.
December 2021

Open Access Article

QUALITY ANALYSIS IN THE INTRLOCKING STONES WITH MARKOV CHAIN MODEL

Dr.R.Arumugam
Assistant Professor, arumugamr@pmu.edu

S.Vinodhini
Research Scholar, Department of Mathematics, Periyar Maniammai Institute of Science & Technology, Thanjavur-613 403 Tamilnadu, India, vinodhinisundarraj97@gmail.com

Abstract

The data explored the assessment of the quality of river sand as an aggregate in place of crushed stones, which is widely used by the majority of manufacturers in the production of interlocking stones. Experimental tests carried out on river sand and crushed rock as aggregates include: moisture content determination, specific gravity, and bulk density to determine the defect rates. The results of the experiments are presented in the Markov Chain Process to find the quality rate of river sand and crushed rock. Statistical quality control is the use of statistical methods in the monitoring and maintenance of the quality of products and services. One method, referred to as "acceptance sampling," can be used when a decision must be made to accept or reject a group of parts or items based on the quality found in the sample. A second method, referred to as statistical process control, uses graphical displays known as control charts to determine whether a process should be continued or should be adjusted to achieve the desired quality.

Keywords: River sand, crushed stone as fine aggregate, cement, compressive strength, Markov Chain, Minitab software

抽象的

数据探讨了评估河砂作为骨料代替碎石的质量，大多数制造商在联锁石生产中广泛使用。对河砂和碎石作为骨料进行的实验测试包括：水分含量测定、比重和堆积密度，以确定缺陷率。实验结果以马尔可夫链过程呈现，以找出河砂和碎石的质量率。统计质量控制是使用统计方法监控和维护产品和服务的质量。当必须根据样品中发现的质量决定接受或拒绝一组零件或物品时，可以使用一种称为"验收抽样"的方法。第二种方法称为统计过程控制，它使用称为控制图的图形显示来确定是否应该继续或调整过程以达到所需的质量。

关键词：河砂、碎石细骨料、水泥、抗压强度、马尔可夫链、Minitab软件

Received: October 05, 2021 / Revised: October 31, 2021 / Accepted: November 30, 2021 / Published: December 31, 2021
About the authors：Dr.R.Arumugam

Corresponding author- *Email:

1. Introduction

SQC employs statistical methods to manage the quality of goods and services. In 1924, Walter A. Shewhart [1] of the Bell Telephone Laboratories laid the foundation for statistical quality control. Since then, the area of SQC has been enriched by the work of numerous statisticians, quality philosophers, and researchers. In 2012, W.A. Shewhart [2] focused on the application of statistics as an aid in maintaining the quality of a manufactured product. The prominent contributors include Zichang He and Wen Jiang [3]. The new Berief Markov chain model overcomes the shortcomings of the classical Markov chain and has an efficient ability to deal with uncertain information. The deep learning r control chart is relatively efficient for monitoring the stimulated and real binary response asymmetric data compared with the r control chart of the generalised linear model. Wei-Heng Huang [5] found that the construction of three combined lognormal X bars and S charts is more effective when the lognormal distribution is more skewed. [6] both practitioners and academics with not only an up-to-date account of SQC but also a sense of the discipline's legitimacy.Michael Stuart et al. [7] the contributions of statistical analysis and methods to modern quality control and improvement. Terna Godfrey Leren et al. [8] developed a statistical quality control approach for monitoring process stability in a table water manufacturing company.Saniga, E.M [9] investigates some design and implementation principles.C.E.Okorie [10], Damjan Skulj [11], range from simple probability models and further to models allowing completely general convex sets of probabilities. Jiawei Yang, Qiangyi Sha [12], the state transition matrix can be complex and volatile for dynamic adjustment to meet the needs of market positioning. Lamiae Douiri [13] discussed the applications of some meta-heuristics to solve supply chain models. Jiju Antony and Michael Sony [14] discuss the usage of the seven quality control tools in the manufacturing and service sectors and the benefits, challenges, and critical success factors for the application of the seven QC tools. Samwel Manyele and Nyakorema Rioba [15] establish a control system for the saccharification process using a quality control chart. Tesfay Gidey, Leakemariam Berhe [16]Assessing the Awareness and Usage of Quality Control Tools with an Emphasis on Statistical Process Control in Ethiopian Manufacturing Industries, just to name a few. R. Arulugam et al. focused on the applications of stochastic models in webpage ranking [17]. The impact of dengue fever in Thanjavur district is based on the statistical study discussed by Dr.R.Arumugam et al. [18]. A statistical study was conducted on the production of crops before and after the Gaja cyclone in the delta region by Dr. Arumugam. [19] R et al.M.Rajathi and R.Arumugam [20] discussed the applications of mobile learning in higher education institutions using a statistical approach.A Markov Model for Prediction of Corona Virus COVID-19 in India was discussed by R. Arulugam et al. [21]. R.Arumugam et al [22] explained how to apply manpower at various stages in business using stochastic models.

The chronological account of statistical methods and statistical thinking for quality control is provided in the section that follows. Next, the debate about whether statistical quality control has evolved or been evolving as an evolutionary or revolutionary research programme is presented. A control chart is intended to monitor process stability and variability. The graph includes a centre line, an upper control limit, and a lower control limit. The Control Chart is one of the most important SQC methods in quality control and improvement.

Methodology

The data were collected in the laboratory using experimental tests and procedures under conductive atmospheric conditions, and simple statistical tools were used for analysis. Various tests on the physical properties and strength parameters of aggregate samples, such as moisture content, bulk density, and specific gravity, were carried out. The data provided detailed experimental procedures on how river sand could be used instead of crushed stone. The standard deviation and the variance were calculated by the tabular form method. The result was used in the Markov Chain Process to find whether the concept is applicable or not. The data assessed the usefulness of available river sand in the replacement of crushed stones in the production of interlocking stones. The behaviour of 100% river sand, 50% river sand, 50% crushed rock, and 100% crushed rock is indicated in the following tables. The variance in the value of aggregates in moisture content determination, specific gravity, and bulk density determination was equally illustrated in the tables

2. Mathematical Model

The mean, X, is a measure of the central tendency of a group of measurements.

Mathematically,

$$\overline{X} = \sum \frac{X_i}{n}$$

$Xi =$ Individual observations and

$n =$ Number of observations in a group

The standard deviation σ is a measure of the dispersion of the measurements from their mean. The mathematical definition is:

$$\sigma = \sqrt{\frac{\sum (X_i - X)^2}{n-1}}$$

The variance (V), is the square of the standard deviation, mathematically, $V = \sigma^2$

$$\text{Moisture content\%} = \frac{M_{wet} - M_{dry}}{m_{dry}} \times 100$$

Where,

M_{wet} = tin + wet soil

M_{dry} = tin + dry soil

m_{dry} = weight of dry soil

$$\text{Specific gravity} = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$

Where,

W_1 = mass of empty pycnometer

W_2 = mass of the empty pycnometer + sample

W_3 = mass of the empty pycnometer + sample+ water

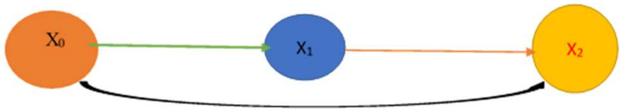
W_4 = mass of empty pycnometer + water

$$\text{Bulk density} = \frac{mass\ of\ samples}{volume}$$

By Markov chain property

Next state = transition matrix × current state

i.e.) $X_i = PX_j$ ………………………(*)



River sand/ crushed rock

Fig 1.1

From fig. 1.1, my assumption is to prove a past state to a future state. From equation (*), we can write, "future state = transition matrix × past state."

i,e) $X_2 = PX_0$ ……………………………(1)

Now I'm going to prove equation (1) by using the Markov chain property.

let, $X_1 = PX_0$ ……………………………(2)

$X_2 = PX_1$ ……………………………(3)

By Markov chain property, the transition probability matrix value should be equal to 1, so I just apply the transition matrix value as 1. Since "the state transition probability matrix of a Markov chain gives the probabilities of transitioning from one state to another in a single time unit", i.e., P = 1.

From equation (2) & (3), I get $X_1 = X_0$ and $X_2 = X_1$ ……………………(4)

From equation (4) , we can write $\mathbf{X_2 = X_0}$ ………………………..(5)

Equation (5) is only possible if X_2 and X_0 are equal to 1 when we add the values column wise.

3. Analysis

4.1 Testing of materials

The procedure of various tests conducted on materials is as follows.

The data assessed the usefulness of available river sand in the replacement of crushed stones in the production of interlocking stones. The variance in the value of aggregates in moisture content determination, specific gravity, and bulk density determination was equally illustrated in the tables and I have collected this data from

https://www.sciencedirect.com/science/article/pii/S2352340918309089

Table 1 Moisture content determination of 100% river sand

Tin no	1A(g)	1B(g)	Mean	range	σ	S^2
Tin+wet soil	68	80	74	12	8.485	72
Tin+dry soil	66.85	79	72.93	12.15	8.591	73.81
Weight of tin	34	40	37	6	4.243	18
Weight of water	1.0	1.0	1	0	0	0
Weight of dry soil	31	34	32.5	3	2.12	4.5
M.C %	3.71	2.85	= 0.86			

Table 2 Moisture content determination of 50%:50% (river sand & crushed rock)

Tin no	2A(g)	2B(g)	Mean	range	σ	S^2
Tin+wet soil	67	80	73.5	13	9.192	84.5
Tin+dry soil	65	78	71.5	13	9.192	84.5
Weight of tin	34	40	37	6	4.243	18
Weight of water	1.0	1.0	1	0	0	0

Weight of dry soil	32	37	34.5	5	3.536	12.5
M.C%	6.25	5.405	= 0.84			

Table 3 Moisture content determination of 100% crushed rock

Tin no	3A(g)	3B(g)	Mean	range	σ	S^2
Tin+ wet soil	60	81	70.4	21	14.849	220.52
Tin+ dry soil	68	79	73.5	11	7.778	60.5
Weight of tin	34	40	37	6	4.243	18
Weight of water	1.0	1.0	1	0	0	0
Weight of dry soil	33	39	36	6	4.243	18
M.C%	5.88	5.12	= 0.75			

Table 4 Specific gravity of 100% river sand

Determination number	1A	1B	mean	range	σ	S^2
Mass of empty pycnometer(g)	170	180	175	10	7.071	50
Mass of empty pycnometer+ sample(g)	270	280	275	10	7.071	50
Mass of empty+ sample+water(g)	526	536	531	10	7.071	50
Mass of samples (g)	100	100	100	0	0	0
Mass of pycnometer+ water	463	474	468.5	11	7.778	60.5
Mass of sample in water(g)	356	356	356	0	0	0
Volume of pycnometer $(cm3)$	290.9	290.9	290.9	0	0	0
Specific gravity	2.70	2.63	= 0.07			

Table 5 Specific gravity of 50%:50% (river sand& crushed rock)

Determination number	2A	2B	mean	range	σ	S^2
Mass of empty pycnometer(g)	180	170	175	10	7.071	50
Mass of empty pycnometer+sample(g)	260	250	255	10	7.071	50
Mass of empty pycnometer+ sample + water(g)	516	507	511.5	9	6.364	40.5
Mass of samples(g)	80	80	80	0	0	0
Mass of pycnometer+ water	466	458	462	8	5.657	32
Mass of sample in water(g)	336	337	336.5	1	0.707	0.5
Volume of pycnometer$(cm3)$	290.9	290.9	290.9	0	0	0
Specific gravity	2.66	2.58	= 0.08			

Table 6 Specific gravity of 100% crushed rock

Determination number	3A	3B	mean	range	σ	S^2
Mass of empty pycnometer(g)	180	170	175	10	7.071	50
Mass of empty pycnometer+ sample(g)	260	250	255	10	7.071	50

Mass of empty pycnometer+ sample+ water(g)	518	508	513	10	7.071	50
Mass of sample(g)	80	80	80	0	0	0
Mass of pycnometer+ water	468	460	464	8	5.657	32
Mass of sample in water(g)	336	336	336	0	0	0
Volume of pycnometer($cm3$)	290.9	290.9	290.9	0	0	0
Specific gravity	2.67	2.50	= 0.17			

Table 7 Bulk density 100% river sand

Determination number	1A	1B	mean	range	σ	S^2
Weight of density container(g)	1840	1840	1840	0	0	0
Percentage of water (added)%	4.000	4.000	4.000	0	0	0
Weight of sample(g)	1736	1680	1708	56	39.597	1568
Weight of container+ sample+ water(g)	3576	3520	3548	56	39.597	1568
Volume of density container($cm3$)	944	944	944	0	0	0
Bulk density	1.84	1.78	= 0.06			

Table 8 Bulk density of 50%:50% (river sand& crushed rock)

Determination number	2A	2B	mean	range	σ	S^2
Weight of density container(g)	1840	1840	1840	0	0	0
Percentage of water added(%)	4.000	4.000	4.000	0	0	0
Weight of sample(g)	1686	1590	1638	96	67.882	4608
Weight of container+ sample+ water(g)	3526	3430	3478	96	67.882	4608
Volume of density container($cm3$)	944	944	944	0	0	0
Bulk density	1.79	1.68	= 0.11			

Table 9 Bulk density of 100% crushed rock

Determination number	3A	3B	Mean	range	σ	S^2
Weight of density container(g)	1840	1840	1840	0	0	0
Percentage of water added(%)	4.000	4.000	4.000	0	0	0
Weight of sample(g)	1646	1580	613	66	46.669	2178
Weight of container+ sample+ water(g)	3486	3420	3453	66	46.669	2178
Volume of density container($cm3$)	944	944	944	0	0	0
Bulk density	1.74	1.67	= 0.07			

4.2 Markov chain process

From the above tables (moisture content, specific gravity, and bulk density), we get

$$X_2 = \begin{bmatrix}0.75\\0.17\\0.07\end{bmatrix}; \qquad P= \begin{bmatrix}0.86 & 0.84 & 0.75\\0.07 & 0.08 & 0.17\\0.06 & 0.11 & 0.07\end{bmatrix}; \qquad X_0 = \begin{bmatrix}0.86\\0.07\\0.06\end{bmatrix}$$

Equation (5), **$X_2 = PX_0$**

$$\begin{bmatrix}0.75\\0.17\\0.07\end{bmatrix} = \begin{bmatrix}0.86 & 0.84 & 0.75\\0.07 & 0.08 & 0.17\\0.06 & 0.11 & 0.07\end{bmatrix}\begin{bmatrix}0.86\\0.07\\0.06\end{bmatrix}$$

1=1, When we add the X2 and X0 values, we get 1.

$\rightarrow X_2 = X_0$

4.3 Control chart

The control chart is a graph used to study how a process changes over time. The data is plotted in time order. A control chart always has a central line for the average, an upper line for the upper control limit, and a lower line for the lower control limit. Control charts for variable data are used in pairs. The control chart measures the performance and continuous monitoring of the process. The control charts are prepared with the help of Minitab software. Test values that fall within the specified range are considered acceptable, and those that fall outside are considered defects. In the control charts below, values that are outside of the control limits are shown in red, while values that are within the control limits are shown in blue.The control charts are as follows:

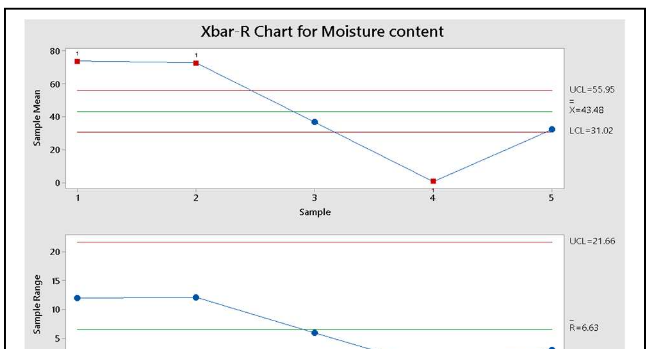


Fig 1. Moisture content determination of 100% river sand

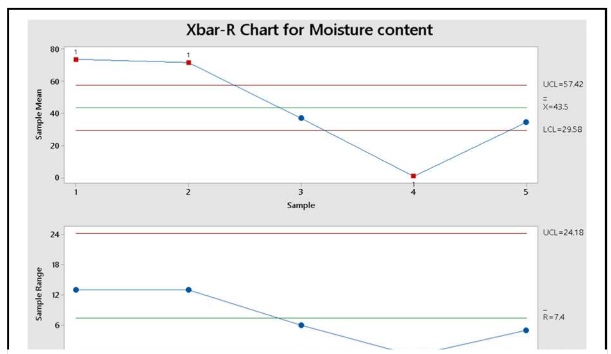
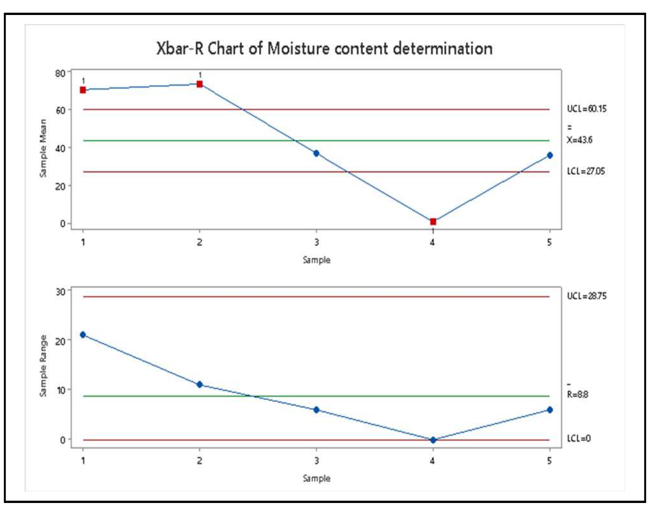


Fig 2. Moisture content determination of 50% river sand: 50% crushed rock



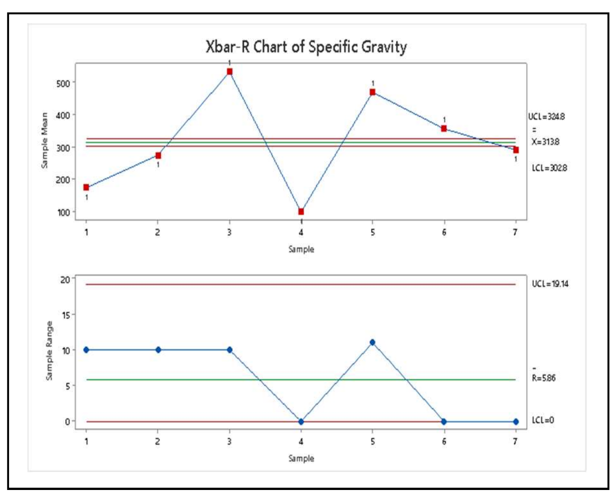
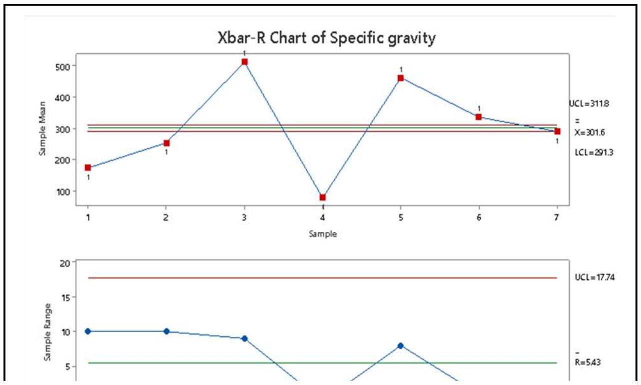


Fig 3: Moisture content determination of 100% crushed rock

Fig 4: Specific gravity of 100% river sand



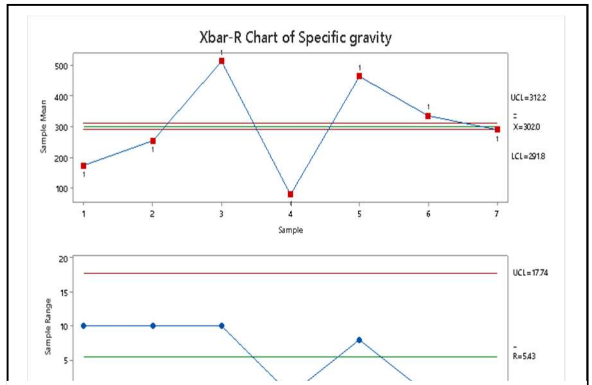


Fig 5: Specific gravity of 50% river sand 50% crushed rock

Fig 6: Specific gravity of 100% crushed rock

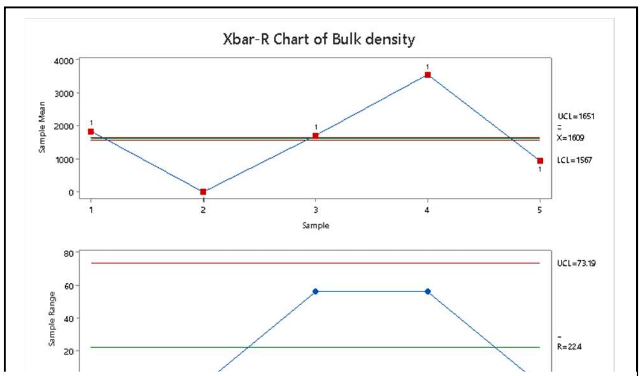


Fig 7: Bulk density of 100% river sand

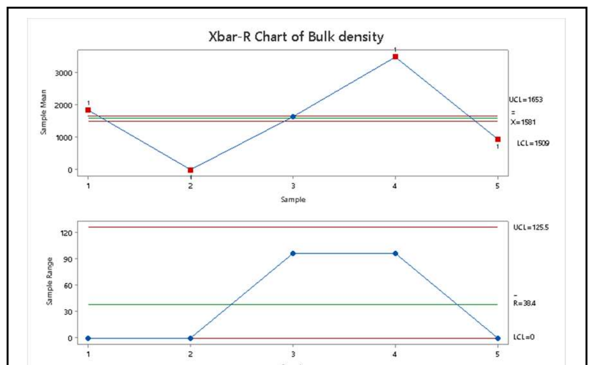


Fig 8: Bulk density of 50% river sand; 50% crushed rock

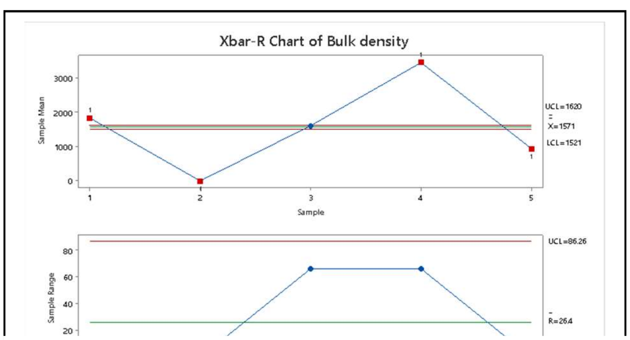


Fig 9: Bulk density of 100% crushed rock

4. Discussion and Result

In the mathematical model, I have explained the past state to the future state instead of the current state to the next state in the Markov chain property. In fig 1.1, X_0 is the past state that represents 100% river sand, X_1 is the current state that represents 50% river sand and 50% crushed rock, and X_2 is the future state that represents 100% crushed rock. From the equations (2) and (3), we get $X_2 = X_0$. This concept is applicable only if we have a past state and the future state value should be equal to 1 when we add them column wise. My secondary data has satisfied the condition, so it has no defect rate.

Next I'm just using my secondary data in Minitab software to determine the method's quality level.Fig. 1 describes the moisture content determination of 100% river sand. The values of the X-bar chart are UCL = 55.95, x = 43.48, and LCL = 31.02. In the X-bar chart, some of the values went out of control. The values of the R chart are UCL = 21.66, R-bar = 6.63, LCL = 0, where the values of the R-bar chart are in the control limit. Fig 2 describes the moisture content determination of 50% river sand and 50% crushed rock. The values of the X-bar chart are UCL = 57.42, x = 43.5, and LCL = 29.58. In the X-bar chart, some of the values went out of control. The values of the R chart are UCL = 24.18, R-bar = 7.4, LCL = 0. Here, the values of the R-bar chart have no defects because the values are within the control limit. Fig 3 describes the moisture content determination of 100% crushed rock. The values of the X-bar chart are UCL = 60.15, x = 43.6, and LCL = 27.05. Here the values of the X-bar chart have defects because the values went beyond the control limit. The values of the R chart are UCL = 28.75, R-bar = 8.8, LCL = 0. Here, the values of the R-bar chart have no defects because the values are within the control limit. Fig. 4 describes the specific gravity of 100% river sand. The values of the X-bar chart are UCL = 324.8, x = 313.8, and LCL = 302.8. Here the values of the X-bar chart have defects because the values went beyond the control limit. The values of the R chart are: UCL = 19.14, R-bar = 5.86, LCL = 0. Here, the values of the R-bar chart have no defects because the values are within the control limit. Fig. 5 describes the specific gravity of 50% river sand and 50% crushed rock. The values of the X-bar chart are UCL = 311.8, x = 301.6, and LCL = 291.3. Here the values of the X-bar chart have defects because the values went beyond the control limit. The values of the R chart are UCL = 17.74, R-bar = 5.43, LCL = 0. Here, the values of the R-bar chart have no defects because the values are within the control limit. Fig. 6 describes the specific gravity of 100% crushed rock. The X-bar chart values are UCL = 312.2, x =302.0, and LCL =291.8. The X-bar chart values have defects because they exceeded the control limit.The values of the R chart are UCL = 17.74, R-bar = 5.43, LCL = 0. Here, the values of the R-bar chart have no defects because the values are within the control limit. Fig. 7 describes the bulk density of 100% river sand. The values of the X-bar chart are UCL = 1651, x = 1609, and LCL = 1567. Here the values of the X-bar chart have defects because the values have gone beyond the control limit. The values of the R chart are UCL = 73.19, R-bar = 22.4, and LCL = 0. Here, the values of the R-bar chart have no defects because the values are within the control limit. Fig. 8 describes the bulk density of 50% river sand and 50% crushed rock. The values of the X-bar chart are UCL = 1653, x = 1581, and LCL = 1509. In the X-bar chart, some of the values went out of control. The values of the R chart are UCL = 125.5, R-bar = 38.4, LCL = 0. Here, the values of the R-bar chart have no defects because the values are within the control limit. Fig. 9 describes the bulk density of 100% crushed rock. The values of the X-bar chart are UCL = 1620, x = 1571, and LCL = 1521. In the X-bar chart, some of the values went out of control. The values of the R chart are UCL = 86.26, R-bar = 26.4, and LCL = 0. Here, the values of the R-bar chart have no defects because the values are within the control limit.

Results

The data assessed the usefulness of available river sand in the replacement of crushed stones in the production of interlocking stones. The variance in the value of aggregates in moisture content determination, specific gravity, and bulk density determination was equally illustrated in the tables. When using Markov chains, the given data does not have any defects in the interlocking stones. Because the data satisfied the condition ($X_2 = X_0$, which is equal to 1), So the data has no defects. When using Minitab software to find the defect rate, we only have the minimum number of defects in the X bar chart and no defects in the R chart. The defects are acceptable, so we can replace them with crushed rock instead of river sand in the construction work.

Conclusion

This paper describes the quality level achieved by using the Markov chain process for river sand as an aggregate in place of crushed rock as an interlocking stone. By using Markov chain, the data has no defects because it satisfies my modified Markov chain condition, so we can apply this process to construction work. When we are using Minitab software, we get only acceptable defects. We can use 100% crushed rock within the given ratio, which means we will get the defect level very low. So we can produce this process for further studies.

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