ANALYZE THE VARIABILITY OF CONCRETE QUALITY IN THE WORK ON THE PROMENADE APARTMENT USING SPC (STATISTICAL PROCCES CONTROL) (Case Study: Queen City Mall Building Project, Hotel and Apartment Promenade)

Dwi Achmad Fauzi[1*], Jannah Rahma A[2], Putri Anggi Permata Suwandi [3], Agung Kristiawan [4]

[1]Faculty of Engineering and Informatics, Universitas PGRI Semarang, Jl. Sidodadi Timur No.24 Semarang, Central Java 50232, Indonesia

[2]Faculty of Engineering and Informatics, Universitas PGRI Semarang, Jl. Sidodadi Timur No.24 Semarang, Central Java 50232, Indonesia

[3]Faculty of Engineering and Informatics, Universitas PGRI Semarang, Jl. Sidodadi Timur No.24 Semarang, Central Java 50232, Indonesia

[4]Faculty of Engineering and Informatics, Universitas PGRI Semarang, Jl. Sidodadi Timur No.24 Semarang, Central Java 50232, Indonesia

*dwiachmadfauzi4@gmail.com

Abstract. Quality control in a job is very important because to know that a job is in accordance with quality standards and is carried out according to the schedule without delays in a project work. The research was conducted so that there was no repetition in a job on the Queen City Mall Building, Hotel and Promenade Apartment project. The method used in this study is the SPC (Statistical Process Control) method. Data collection was obtained from primary data in the form of concrete compressive strength data from the laboratory and secondary data in the form of RKS_STRUKTUR Atas_R0_11-12-2021. The results of the study showed that there were deviations in the quality of the concrete fc 25 MPa, 30 MPa, and 35 MPa which were under both lower and upper control without affecting the concrete quality standard.

Keywords : Quality control, Statistical Process Control (SPC)

1. Introduction

The work of a building construction will require a large volume of concrete. It is necessary to control the quality of concrete so that during the work there are no errors that will make the work repeated. The case study used is concrete quality data on beam and plate columns on floors 1-18.

To overcome this, control is needed to find out deviations that occur during the casting process. Based on the description above, the formulation of the problem will be obtained as follows:Based on the description of the background above, it can be obtained the formulation of the problem as follows:

a. What are the trends or statistics on concrete quality that occurred during the construction process of the Promenade Apartment

The objectives to be achieved in this research are:

a. Analyze trends or statistics that occur and determine plans for corrective steps that occur during the process of taking samples of the results of casting work on the Promenade Apartment project

The limitations of the problem are as follows:

a. Concrete compression test data was taken from April to November 2022
b. Data from the compressive test results were taken in the form of column, beam and plate compression test data.
c. The study did not conduct material tests

2. Methods

In general, research is conducted through several stages as follows:

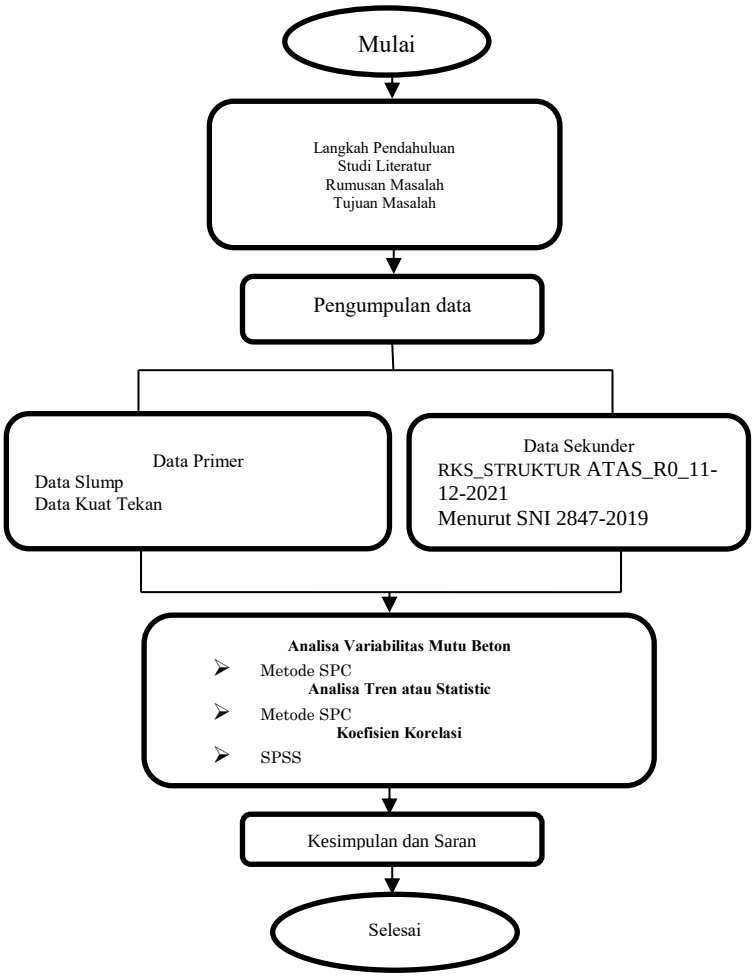

Figure 2. 1 Flowchart Study
Source : Researcher, 2022

The location of the research was carried out at the Appartement Promenade project. Data collection out with way:

a. Primary Data
   Primary data is the main data used in a study that is a obtained directly or from the main source. The data is directly realated to research conducted to determine variability , trends and relationship or corellations. Included in the primary data are pressure test and slump test.
b. Secondary Data
   Secondary data is that has been processed beforehand, secondary data sources are in the form of journal, articles and publications. Which includes secondary data in this study is RKS_STRUKTUR ATAS_R0_11-12-2021

3. Results and Discussion

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3.1 Analysis of Concrete Quality Statistical Process Control

SPC is a statistical control tool using the help of a control chart, namely the $\overline{X}$ chart. Average control charts and upper and lower ranges used to monitor the control process. On the $\overline{X}$ chart and R chart there are CL (control line), UCL (upper control line) and LCL (lower control line). To calculate the $\overline{X}$ control chart, the following steps are taken:

- CL line for each concrete quality
  - fc 25 MPa
    $CL = \overline{\overline{X}} = 33{,}18$ MPa
  - fc 30 MPa
    $CL = \overline{\overline{X}} = 36{,}80$ MPa
  - fc 35 MPa
    $CL = \overline{\overline{X}} = 47{,}43$ MPa
- UCL line for each concrete quality
  - fc 25 MPa
    $= \overline{\overline{X}} + (A2 \text{ x } \bar{R})$
    $= 33{,}18 + (188 \text{ x } 1{,}70) 36{,}38$ MPa
  - fc 30 MPa
    $= \overline{\overline{X}} + (A2 \text{ x } \bar{R})$
    $= 36{,}8 + (1.88 \text{ x } 1{,}5) = 39{,}63$ MPa
  - fc 35 MPa
    $= \overline{\overline{X}} + (A2 \text{ x } \bar{R})$
    $= 47{,}43 + (1.88 \text{ x } 3{,}18) 53{,}40$ MPa
- LCL line for each concrete quality
  - fc 25 MPa
    $= \overline{\overline{X}} - (A2 \text{ x } \bar{R})$
    $= 33{,}18 - (1.88 \text{ x } 1{,}70) = 29{,}98$ MPa
  - fc 30 MPa
    $= \overline{\overline{X}} - (A2 \text{ x } \bar{R})$
    $= 36{,}80 - (1.88 \text{ x } 1{,}5) = 33{,}98$ MPa
  - fc 35 MPa
    $= \bar{\bar{X}} - (A2 \text{ x } \bar{R})$
    $= 47{,}43 - (1.88 \text{ x } 3{,}18) = 41{,}45$ MPa

The limits of the control chart R are carried out in the following steps:

- CL line for each concrete quality
  - fc 25 MPa
    $= \overline{R} = 1{,}7$ MPa

- fc 30 Mpa
  $= \overline{R} = 1{,}5$ MPa
- fc 35 MPa
  $= \overline{R} = 3{,}18$ MPa

➢ UCL line for each concrete quality

- fc 25 MPa
  $= D4\ x\ \overline{R}$
  $= 3{,}269\ x\ 1{,}7\ MPa = 5{,}57$ MPa
- fc 30 MPa
  $= D4\ x\ \overline{R}$
  $= 3{,}269\ x\ 1{,}5\ MPa = 4{,}9$ MPa
- fc 35 MPa
  $= D4\ x\ \overline{R}$
  $= 3{,}269\ x\ 3{,}18\ MPa = 10{,}39$ MPa

➢ LCL line for each concrete quality

- fc 25 MPa
  $=D3\ x\ \overline{R}$
  = 0 x 1,7 MPa = 0 MPa
- fc 30 MPa
  $= D3\ x\ \overline{R}$
  = 0 x 1,5 MPa = 0 MPa
- fc 35 MPa
  $= D3\ x\ \overline{R}$
  = 0 x 3,18 MPa = 0 MPa

From the calculation above, for each concrete quality there is uncontrolled data, improvements will be made by eliminating uncontrolled data so that the data for each concrete quality is within control or controlled limits, for the steps as follows: $\overline{X}$ and R Control Map Improvements

- fc 25 MPa

$$\bar{\bar{X}} = \frac{\sum \overline{X}}{n - banyaknya\ data\ perbaikan}$$

$$\bar{\bar{X}} = \frac{1265{,}32}{57 - 18}$$

$$\bar{\bar{X}} = \frac{1265{,}32}{39} = 32{,}44 \text{ MPa}$$

$$\overline{R} = \frac{\sum R}{n - banyaknya\ data\ perbaikan}$$

$$\overline{R} = \frac{866{,}6}{57 - 18}$$

$$\overline{R} = \frac{77{,}14}{39} = 1{,}98 \text{ MPa}$$

Determine the UCL and LCL of the $\overline{X}$ control chart

UCL $= 32{,}44 + (1{,}88\ x\ 1{,}98) = 36{,}16$ MPa

LCL $= 32{,}44 - (1{,}88\ x\ 1{,}98) = 28{,}73$ MPa

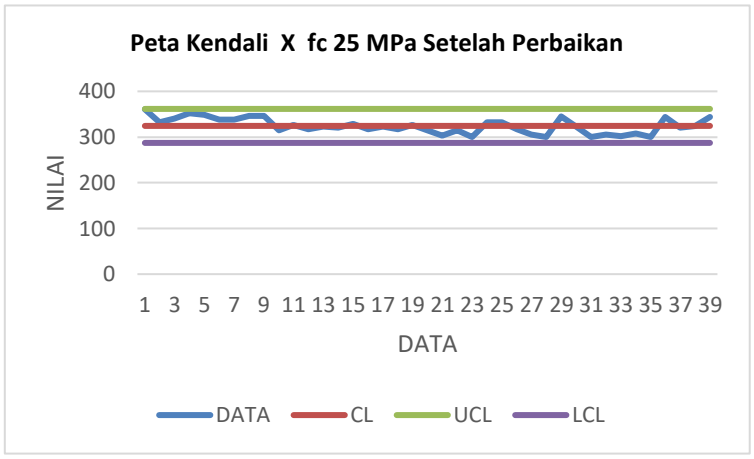

Figure 3. 1 Control Map $\overline{X}$ fc 25 MPa After Repair
Source : Researcher, 2022

Determine the UCL and LCL of the R control chart

UCL = $D4\ x\ \overline{R}$
= 3,269 x 1,98 = 6,47 MPa

LCL = $D3\ x\ \overline{R}$
= 0 x 1,98 = 0

CL = $\overline{R}$ = 1,98 MPa

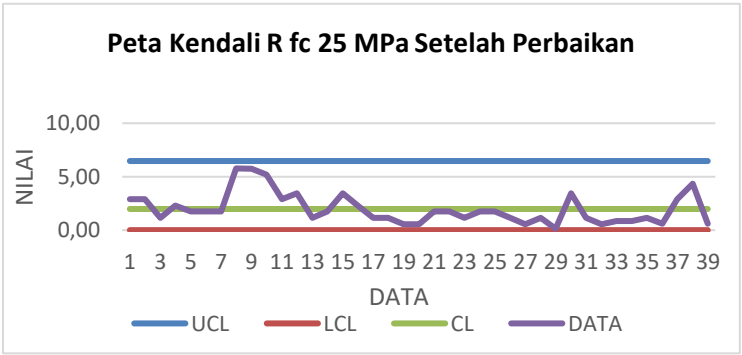

Figure 3. 2 Control Map R fc 25 MPa After Repair
Source : Researcher, 2022

Table 3. 1 Result Out Of Control fc 25 MPa
Source : Researcher, 2022

Data *Out Of Controll* fc 25 MPa

Supplayer	Tanggal cor	Tanggal test	Mutu beton (MPa)	Lokasi	Umur (hari)	Hasil Kuat Tekan (MPa)
MJB	05-Jun-22	03-Jul-22	25	Slab GF as B13-B20/BN-BR	28	39,6
						39,6
MJB	10-Jun-22	08-Jul-22	25	Slab Lantai LG as B20'-B22'/BM-BK4'	28	37,33
						38,46
MJB	11-Jun-22	09-Jul-22	25	Slab Lantai LG as B14-B20/BL-BF	28	35,81
						36,33

VUB	07-Jul-22	04-Aug-22	25	Slab Lt 3 apartemen as BP-BR/B18-B21 zona 2	28	37,9 36,77
VUB	17-Jul-22	14-Aug-22	25	slab lt UG as B1-B4'/BR-BS dan lt 4th Apartment as BP-BR/B15-B21'	28	37,9 37,33
VUB	23-Jul-22	20-Aug-22	25	Slab Lt 5 Apartment as B15-B21/BL-BP'	28	41,86 39,6
VUB	04-Aug-22	01-Sep-22	25	Slab Lt 6 Apartemen as BR-BS/B15-B21	28	28,28 29,98
VUB	07-Aug-22	04-Sep-22	25	Slab Lt 7 Apartemen as BL-BP/B15-B21	28	25,38 26,43
VUB	30-Sep-22	28-Oct-22	25	Slab Lt 13 Apartemen as BP-BR/B15-B21	28	27,72 28,85
VUB	01-Oct-22	29-Oct-22	25	Slab Lt 13th Apartment as B15-B21/BR-BS	28	28,28 29,98
VUB	06-Oct-22	03-Nov-22	25	SWA4 & SWA5 Lt 15 Apartemen	28	28,28 29,41
VUB	09-Oct-22	06-Nov-22	25	Shearwall SWA1 lt 15th Apartment dan Ring Balok P1 hotel	28	28,28 27,15
VUB	13-Oct-22	10-Nov-22	25	Shearwall Lt 17 Apartemen SWA4; SWA5 - Kolom Lt P4 KM59(T) as BJ/B14; KM41 as BK/B14	28	28,28 28,28
VUB	21-Oct-22	18-Nov-22	25	Kolom Lt 15th Apartment as B21/BL; B20/BL; B15/BN dan Kolom lt P6 ramp putar as B12'/BF; B10/BE	28	28 28,85
VUB	04-Nov-22	02-Dec-22	25	Kolom lt 17th Apartment as B20/BS; B21/BS; B20/BR; B21/BR; B20/BQ; B21/BQ - Kolom Lt P4 KM28 as B3'/BG'; KM21A as B3'/BJ' - Tangga ST#4 lt P1 ke bordes	28	29,41 28,28
VUB	18-Nov-22	16-Dec-22	25	Slab Lt 18th Apartment as B15-B21/BQ-BM	28	27,72 29,98

VUB	29-Nov-22	27-Dec-22	25	Kolom lt 19th Apartment as B20/BP; B21/BP; B20/BN; B21/BN - Kolom Lt P4 as B1/BJ; B1/BK - Kolom Lt P7 as B4/BB; B4/BB7	28	46,38 46,81

- fc 30 MPa

$$\bar{\bar{X}} = \frac{\sum \bar{X}}{n - banyaknya\ data\ perbaikan}$$

$$\bar{\bar{X}} = \frac{925{,}99}{41 - 15}$$

$$\bar{\bar{X}} = \frac{925{,}99}{26} = 35{,}61 \text{ MPa}$$

$$\bar{R} = \frac{\sum R}{n - banyaknya\ data\ perbaikan}$$

$$\bar{R} = \frac{37{,}25}{41 - 15}$$

$$\bar{R} = \frac{37{,}25}{26} = 1{,}43 \text{ MPa}$$

Determine the UCL and LCL of the X control chart

$$\text{UCL} = 35{,}61 + (1{,}88\ x\ 1{,}43) = 38{,}31 \text{ MPa}$$

$$\text{LCL} = 35{,}61 - (1{,}88\ x\ 1{,}43) = 32{,}92 \text{ MPa}$$

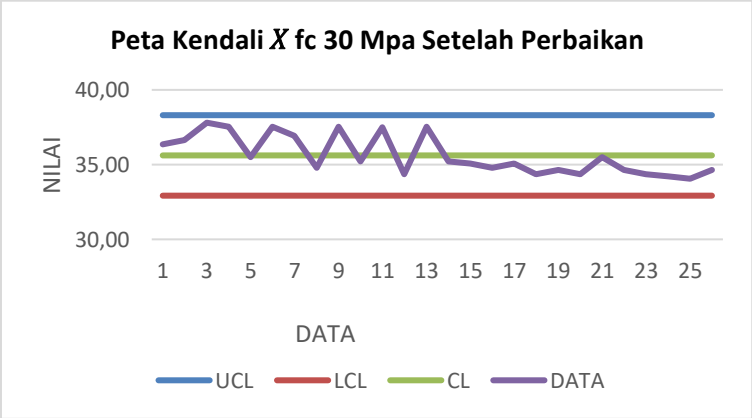

Figure 3. 3 Control Map $\bar{X}$ fc 30 MPa After Repair
Source : Researcher, 2022

Determine the UCL and LCL of the $\bar{X}$ control chart

$$\text{UCL} = D4\ x\ \bar{R}$$
$$= 3{,}269\ x1{,}43 = 4{,}68 \text{ MPa}$$

$$\text{CL} = \bar{R} = 1{,}43 \text{ MPa}$$

$$\text{LCL} = D3\ x\ \bar{R}$$
$$= 0\ x\ 1{,}43 = 0$$

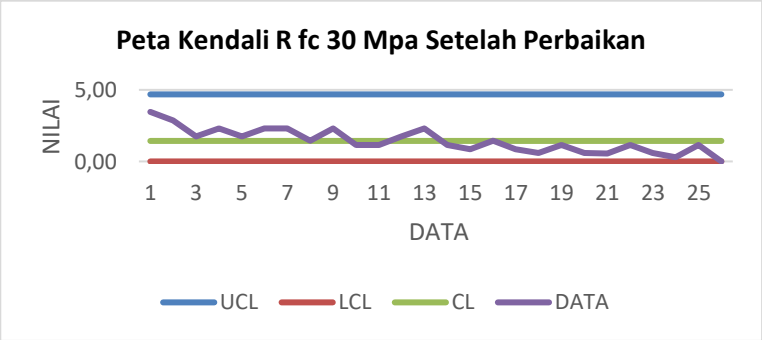

Figure 3. 4 Control Map R fc 30 MPa After Repair
Source : Researcher, 2022

Table 3. 2 Result Out Of Control 30 MPa

Source : Researcher, 2022

Data Out Of Controll fc 30 MPa

Supplayer	Tanggal cor	Tanggal test	Mutu beton (MPa)	Lokasi	Umur (hari)	Hasil Kuat Tekan (MPa)
VUB	09-Apr-22	07-May-22	30	slab lt lg as bk4-bn/b12-b20	28	43,56
						45,25
MJB	26-May-22	23-Jun-22	30	Slab Lt.LG as B15 - B20/ BS-BQ	28	39,6
						41,29
MJB	02-Jun-22	30-Jun-22	30	Slab Lt.LG as B20-B12/BM-BS'	28	42,42
						42,99
MJB	05-Jun-22	03-Jul-22	30	Dinding RW Lt LG as b20-b21/bs	28	46,38
						43,56
MJB	16-Aug-22	13-Sep-22	30	Slab lt 8th Apartment as BP-BR/B15-B21	28	32,24
						31,11
MJB	16-Aug-22	13-Sep-22	30	Kolom lt P2 as B6'/BF - kolom lt 8th Apartment as B21/BP; B18/BM; B15/BM; B15/BL; B8/BL - Kolom lt GF as B6/BR' - kolom lt P1 as B11'/BN; B9/BN'	28	40,16
						41,29
MJB	03-Sep-22	01-Oct-22	30	Kolom Lt 10 Apartemen as BR/B21; BR/B20; BQ/B21; BQ/B20; SWA3 as BP'/B15-B18' Lt 12 Apartemen; Kolom Lt P3 as B5'/BG'; Kolom Lt P2 as BJ'/B4	28	37,9
						40,16
VUB	10-Sep-22	08-Oct-22	30	Slab Lt 11th Apartment as B15-B21/BP-BR	28	27,89
						29,01
MJB	13-Sep-22	11-Oct-22	30	Kolom Lt 11 Aapartemen as BR/B18; BR/B20; BR/B15; BS/B21; BS/B20; SWA3 as BP'/B15-B18 Lt 13 Apartemen; Kolom Lt P3 as BJ'/B.2.2	28	37,33
						39,03

MJB	14-Sep-22	12-Oct-22	30	Kolom Lt P3 as B17/BK4; B14/BK; B17/BJ; Kolom Lt P4 as B5'/BC; Kolom Lt 11 Apartemen as B15/BS; B18/BS	28	32,81
						34,51
MJB	22-Sep-22	20-Oct-22	30	Kolom Lt 12th Apartment as BR/B18 danKolom Lt P4 Ramp 01 KM32 as B10/BB'; B11/BB7	28	40,73
						37,33
MJB	24-Sep-22	22-Oct-22	30	Kolom lt 12th Apartment as B15/BS; B18/BS dan Shearwall SWA5 lt 14th Apartment	28	37,9
						39,6
MJB	28-Sep-22	26-Oct-22	30	SWA 2 & SWA3 LT 14 APARTEMEN LANJUTAN	28	39,6
						37,9
VUB	27-Oct-22	24-Nov-22	30	Slab Lt 16 Apartemen as BQ-BS/B15-B21	28	32,18
						32,24
VUB	28-Oct-22	25-Nov-22	30	Kolom lt 16 Apartemen as BQ/B21; BQ/B20; BR/B21; BR/B20; BS/B21; BS/B20; SWA 5 Lt 18 Apart; Kolom Lt P3 as BQ/B13; BN9/B8	28	30,38
						30,90

- fc 35 MPa

$$\bar{\bar{X}} = \frac{\sum \bar{X}}{n - banyaknya\ data\ perbaikan}$$

$$\bar{\bar{X}} = \frac{1879{,}69}{56 - 18}$$

$$\bar{\bar{X}} = \frac{1879{,}69}{38} = 49{,}47 \text{ MPa}$$

$$\bar{R} = \frac{\sum R}{n - banyaknya\ data\ perbaikan}$$

$$\bar{R} = \frac{75{,}29}{56 - 18}$$

$$\bar{R} = \frac{75{,}29}{38} = 1{,}98 \text{ MPa}$$

Determine the UCL and LCL of the $\bar{X}$ control chart

$$\text{UCL} = 49{,}47 + (1{,}88\ x\ 1{,}98) = 53{,}19 \text{ MPa}$$

$$\text{LCL} = 49{,}47 - (1{,}88\ x\ 1{,}98) = 45{,}74 \text{ MPa}$$

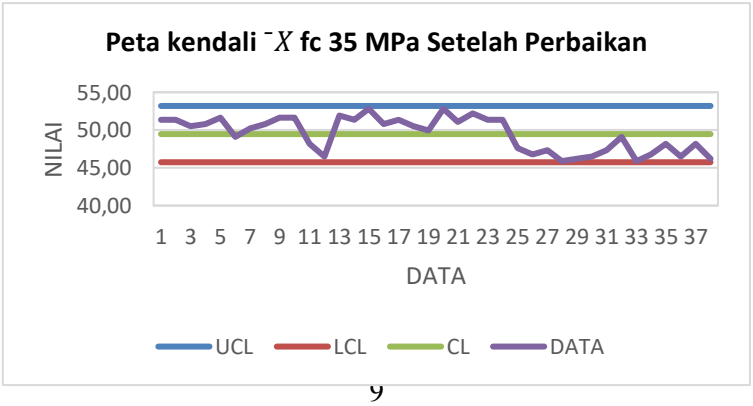

Figure 3. 5 Control Map $\bar{X}$ fc 35 MPa After Repair
Source : Researcher, 2022

Determine the UCL and LCL of the R control chart

UCL = $D4\ x\ \overline{R}$

= $3{,}269\ x1{,}98 = 6{,}48$ MPa

CL = $\overline{R} = 1{,}98$ MPa

LCL = $D3\ x\ \overline{R}$

=$0\ x1{,}98 = 0$

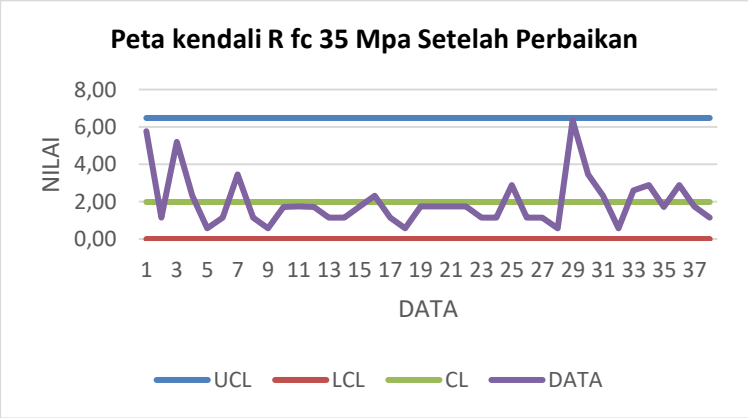

Figure 3. 6 Control Map R fc 35 MPa After Repair
Source : Researcher, 2022

Table 3. 3 Result Out Of Control fc 35 MPa
Source : Researcher, 2022

Data *Out Of Control* fc 35 MPa

Supplayer	Tanggal cor	Tanggal test	Mutu beton (MPa)	Lokasi	Umur (hari)	Hasil Kuat Tekan (MPa)
VUB	13-Apr-22	11-May-22	35	Kolom Lt LG as B15-B18/BN-BL	28	49,78
						33,94
MJB	27-May-22	24-Jun-22	35	SWA 1 as BR'/B15-B19	28	42,42
						41,29
MJB	28-May-22	25-Jun-22	35	Kolom KA1C as BR/B15; KA2B as BS/B15 Lt.LG	28	41,29
						40,73
MJB	03-Jun-22	01-Jul-22	35	Kolom KA-2A as B21/BS; Kolom KA-1 as B21/BR	28	49,21
						56,57
MJB	07-Jun-22	05-Jul-22	35	Slab GF as B13-B20/BQ-BS	28	32,81
						40,73
MJB	17-Jun-22	15-Jul-22	35	Kolom Lt UG type KM37 as B4/BR; B6/BR; B9/BR; B11/BR & KM33 as B4/BA7; KM25A as B4/BB dan Kolom lt LG type KM42 as B17/BJ dan KM7 as B16/BG	28	39,03
						37,9
MJB	19-Jun-22	17-Jul-22	35	Shearwall Lt UG/2nd type SWA1 dan SWA4	28	50,34
						51,47
VUB	19-Jul-22	16-Aug-22	35	Kolom Lt 4 Apartemen as BR/B20; BR/B21; BS/B21/; BS/B20 dan SWA1 as BQ'/B15-B19 Lt 6	28	36,77
						43,56

VUB	24-Jul-22	21-Aug-22	35	Kolom lt 5th Apartment type KA2 as B20/BL; KA2A as B21/BL; KA1 as B21/BN; KA1B as B20/BN; KA1 as B21/BP dan SWA4 lt 6th - 7th Apartment	28	42,42
						44,69
MJB	27-Jul-22	24-Aug-22	35	Kolom Lt 5 Apartemen as BR/B18; SWA2 as BQ/B15-B19 Lt 8; SWA5 as BN9'/B17-B19 Lt 8	28	40,94
						43,13
VUB	28-Jul-22	25-Aug-22	35	kolom lt 5th Apartment type KA2A as B21/BS; KA2 as B20/BS; KA2 as B18/BS; KA2B as B15/BS; KA1C as B15/BR; SWA5 kecil; Kolom H2/HC lt Mezzanine; Balok corbell A9/AJ lt P4 (2)	28	45,82
						35,64
MJB	05-Aug-22	02-Sep-22	35	Kolom lt 6th Apartment type KA2 as B20/BS; KA2B as B15/BS; KA1C as B15/BR	28	43,13
						41,5
VUB	06-Aug-22	03-Sep-22	35	Kolom lt 6th Apartment KA2 as B18/BS; KA2A as B21/BS; SWA5 lt 7th ke 8th Apartment	28	38,23
						37,19
MJB	08-Aug-22	05-Sep-22	35	Shearwall type SWA2 lt 8th ke 9th Apartment dan kolom lt 7th Apartment type KA2A as B21/BL; KA2 as B20/BL; KA1B as B20/BN; KA1 as B21/BN; KA1 as B21/BP;	28	41,86
						44,12
MJB	09-Aug-22	06-Sep-22	35	Kolom Lt 7 Apartemen as BL/B15; BL/B18; BM/B18; BP/B20	28	41,09
						43,9
VUB	10-Aug-22	07-Sep-22	35	Kolom lt 7th Apartment type KA1 as B21/BQ; B21/BR; B20/BQ; KA1C as B15/BM; SWA5 mini - SWH3 lt UG - kolom Lt 1 type KH6A as H5/HB	28	37,9
						39,03
VUB	11-Aug-22	08-Sep-22	35	Kolom Lt 7th Apartment as B18/BR dan B20/BR	28	39,03
						40,16
VUB	13-Aug-22	10-Sep-22	35	Kolom Lt 7th Apartment as B15/BR dan B15/BS	28	40,09
						38,44

From the graph above, improvements have been made, so that on each graph of the concrete quality of the $\overline{X}$ and R control charts nothing is out of control or in control.

After making improvements to the control chart then calculating the index capability value for each concrete quality, for the steps as follows:

- Quality capability fc 25 MPa ≈ 250 kg/cm^2

  $LSL = 250\ kg/cm^2$

  $\bar{\bar{X}} = 324{,}4\ kg/cm^2$

  $\sigma = \frac{\bar{R}}{d_2} = \frac{19{,}8}{1{,}128} = 17{,}55$ kg/cm^2

  $cp = \frac{\bar{\bar{X}} - LSL}{3\sigma}$

  $\frac{324{,}4-250}{3(17{,}55)} = \frac{69{,}34}{52{,}59} = 1{,}41$ kg/cm^2

- Quality capability fc 30 MPa ≈ 300 kg/cm^2

  $LSL = 300\ kg/cm^2$

  $\bar{\bar{X}} = 356{,}1$ kg/cm

  $\sigma = \frac{\bar{R}}{d_2} = \frac{14{,}3}{1{,}128} = 11{,}17$ kg/cm^2

  $cp = \frac{\bar{\bar{X}} - LSL}{3\sigma}$

  $\frac{356{,}1-300}{3(11{,}17)} = \frac{56{,}1}{33{,}51} = 1{,}67$ kg/cm^2

- Quality capability fc 35 MPa ≈ 350 kg/cm^2

  $LSL = 350/cm^2$

  $\bar{\bar{X}} = 494{,}7\ kg/cm^2$

  $\sigma = \frac{\bar{R}}{d_2} = \frac{19{,}8}{1{,}128} = 17{,}55$ kg/cm^2

  $cp = \frac{\bar{\bar{X}} - LSL}{3\sigma}$

  $\frac{494{,}7-350}{3(17{,}55)} = \frac{144{,}7}{52{,}65} = 2{,}74$ kg/cm^2

The results of the capability calculation for each concrete quality of 25 MPa, 30 MPa and 35 MPa have values of 1.41 %, 1.67 % and 2.74 % where cp> 1 these values illustrate that the value of capability is of good quality.

4. Conclusions and Recommendations

A. Conclusion

1. The results of deviations that occur in each fc 25 MPa quality are 18 data, the results of these deviations can be seen in table 3.1 above. then for the quality of fc 30 MPa there are 15 data coming out of the control chart which can be seen in table 3.2 above. then on the fc quality of 35 MPa there are 18 out of control data contained in table 3.3 above. Improvements were made by deleting data that came out of the control chart for each concrete quality. So by deleting data that comes out of the control chart, the data obtained will be controlled.

B. Suggestion

1. The results of deviations that occur are still too high, this can occur due to environmental factors, humans, machines and the methods used. In the future it is necessary to pay attention to these factors such as environmental factors and human factors. Environmental factors can be overcome by examining or understanding the condition of the surrounding environment. Then for the human factor, accuracy is carried out in carrying out a job so that the results obtained can be maximized and in accordance with what has been planned. this is done so that the results obtained from the laboratory are the same as those in the field and in accordance with a predetermined plan

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References

[1] Ahuja, H. N., Dozzi, S. P., & Abourizk, S. M. (1994). *Project management: techniques in planning and controlling construction projects*. John Wiley & Sons.

[2] Gardjito, E., Limantara, A. D., Subiyanto, B., & Mudjanarko, S. W. (2017). Pengendalian Mutu Beton dengan Metode Control Chart (SPC) dan Process Capability (SIX-SIGMA) Pada Pekerjaan Konstruksi. *U KaRsT*, *1*(2), 80-105.

[3] Indonesia, B. S. N. (2002). SNI 03-2847-2002 Tentang Tata Cara Perhitungan Struktur Beton untuk Bangunan Gedung. *Jakarta: Badan Standar Nasional Indonesia*.