ANOVA

Code

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Hide

```
library(tidyverse)
library(openintro)
library(ggplot2)
library(DescTools)
library(gridExtra)
library(car)
```

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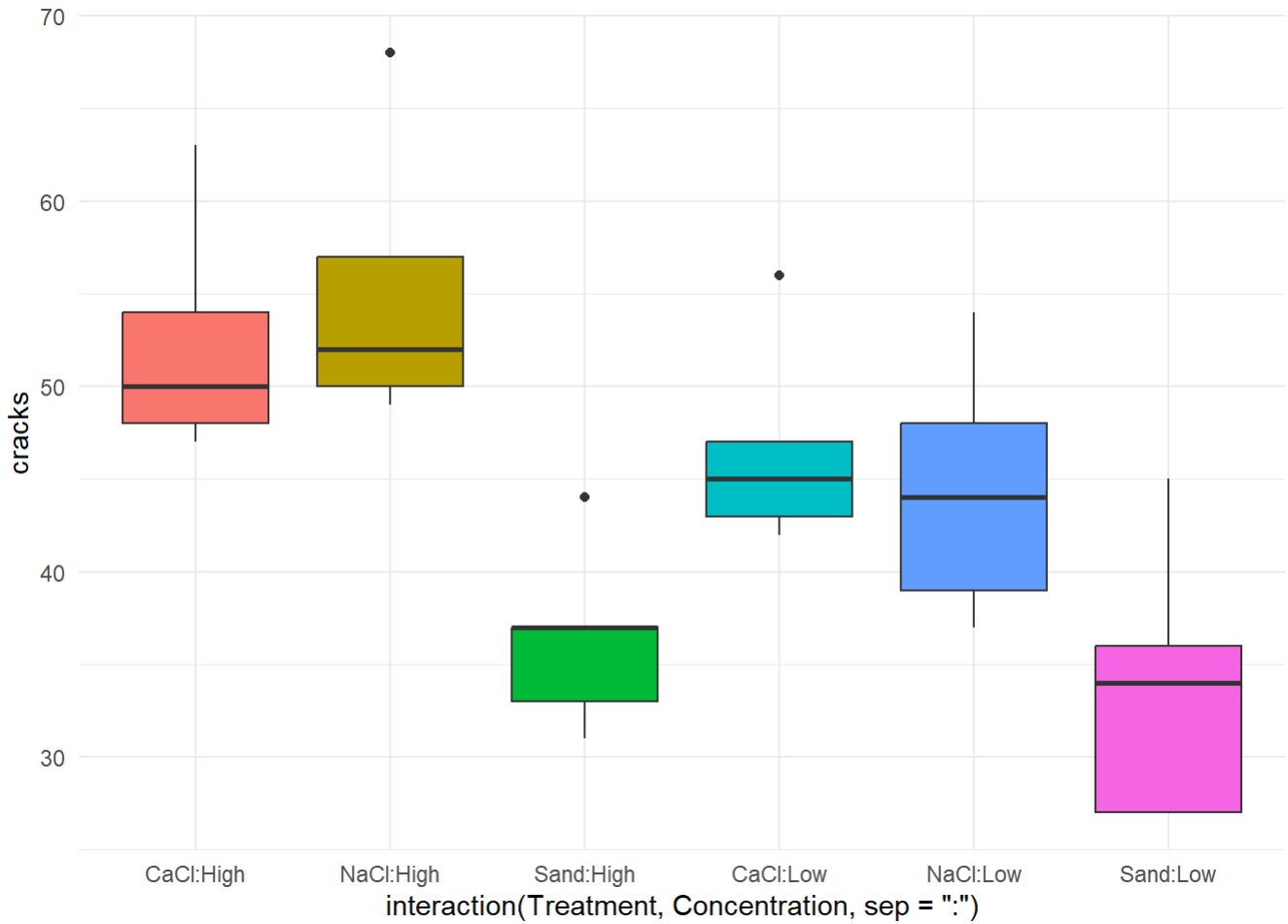
```
crack.data <- read.table(header=TRUE, text="
Roadway cracks  Treatment   Concentration
1   37  NaCl    Low
1   49  NaCl    High
1   43  CaCl    Low
1   47  CaCl    High
1   27  Sand    Low
1   33  Sand    High
2   39  NaCl    Low
2   50  NaCl    High
2   42  CaCl    Low
2   48  CaCl    High
2   27  Sand    Low
2   31  Sand    High
3   48  NaCl    Low
3   52  NaCl    High
3   47  CaCl    Low
3   50  CaCl    High
3   36  Sand    Low
3   37  Sand    High
4   44  NaCl    Low
4   57  NaCl    High
4   45  CaCl    Low
4   54  CaCl    High
4   34  Sand    Low
4   37  Sand    High
5   54  NaCl    Low
5   68  NaCl    High
5   56  CaCl    Low
5   63  CaCl    High
5   45  Sand    Low
5   44  Sand    High
")

ggplot(crack.data, aes(x=interaction(Treatment,Concentration, sep=":"),
                       y=cracks,
                       fill=interaction(Treatment,Concentration, sep=":"))) +
```

```
  geom_boxplot(show.legend = FALSE) +
  theme_minimal()
```



Exercise 1

Statistical Model for this Experiment

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```
summary(
  RCB.model <- aov(cracks ~ Roadway + Treatment*Concentration, data=crack.data)
)
```

```
##                          Df Sum Sq Mean Sq F value   Pr(>F)
## Roadway                   1  821.4   821.4  83.226 4.20e-09 ***
## Treatment                 2 1411.8   705.9  71.523 1.34e-10 ***
## Concentration             1  307.2   307.2  31.126 1.12e-05 ***
## Treatment:Concentration   2   85.4    42.7   4.326   0.0254 *
## Residuals                23  227.0     9.9
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Exercise 2

Interaction plot to display the Treatment:Concentration interaction.

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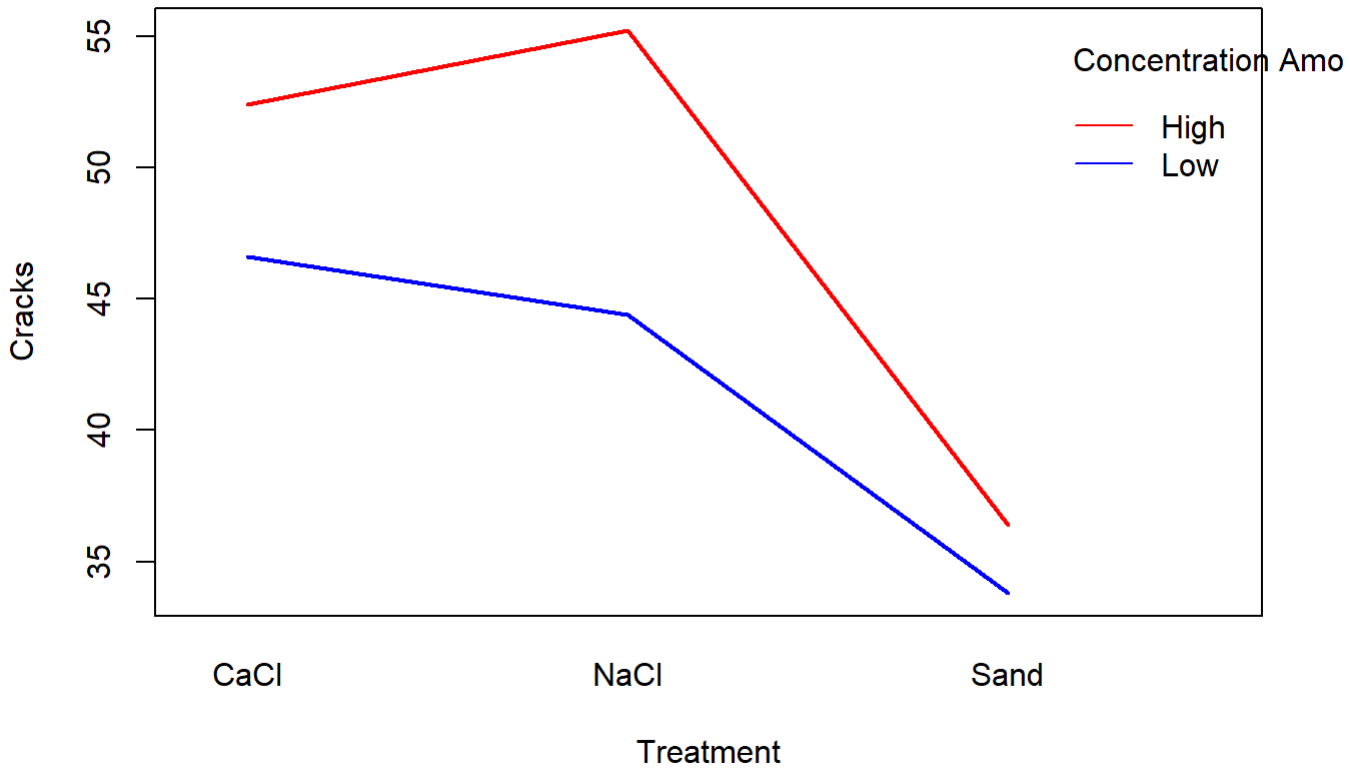
```
interaction.plot(x.factor=crack.data$Treatment,
                 trace.factor=crack.data$Concentration,
                 response=crack.data$cracks,
                 fun=mean,
                 xlab="Treatment", ylab="Cracks",
                 trace.label = "Concentration Amount",
                 col=c("red", "blue", "orange"), lty=1, lwd=2)
```



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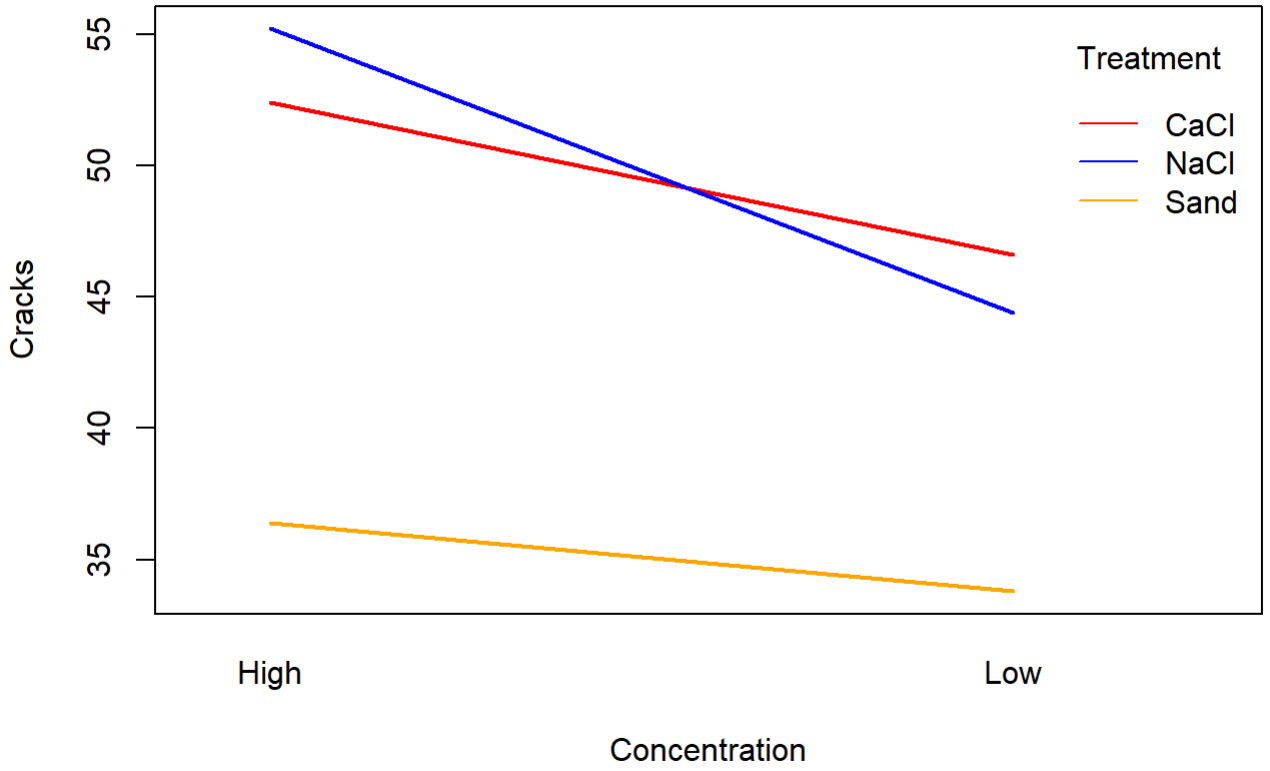
```
interaction.plot(x.factor=crack.data$Concentration,
                 trace.factor=crack.data$Treatment,
                 response=crack.data$cracks,
                 fun=mean,
                 xlab="Concentration", ylab="Cracks",
                 trace.label = "Treatment",
                 col=c("red", "blue", "orange"), lty=1, lwd=2)
```



Exercise 3

Factorial RCB ANOVA to determine the effect of Treatment and Concentration on the number of cracks.

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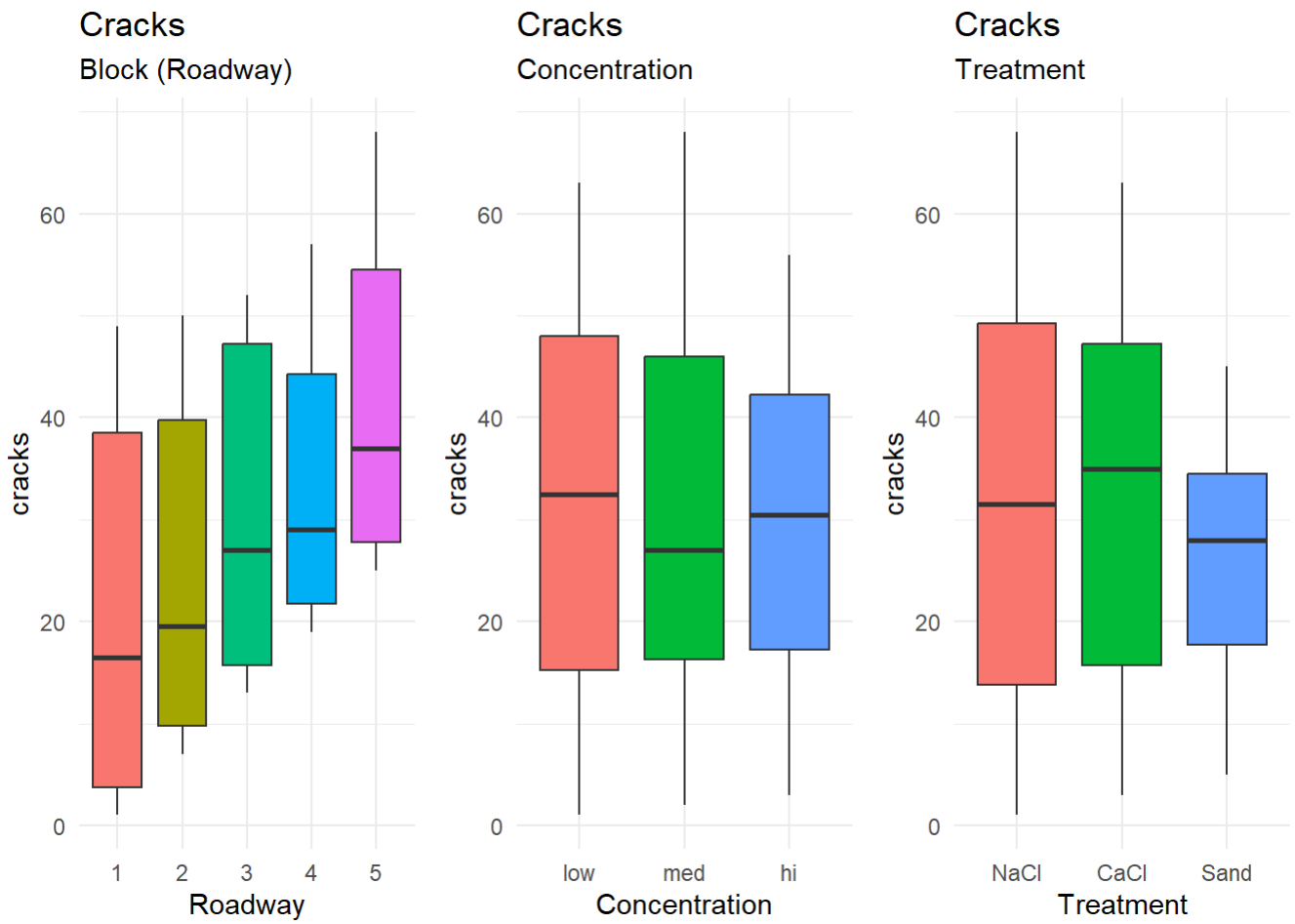
```
Roadway <- factor( c(rep("1", 6), rep("2", 6), rep("3", 6), rep("4", 6), rep("5", 6)), levels=c("1", "2", "3", "4","5"))

Concentration <- factor(rep( c(rep("low", 1), rep("med", 1), rep("hi", 1)),1),
               levels=c("low", "med", "hi"))

Treatment<- factor( c(rep("NaCl", 2), rep("CaCl", 2), rep("Sand", 2)),
                    levels=c("NaCl","CaCl","Sand"))

cracks <- crack.data$cracks %>% c(1:30)

crack.data <- data.frame(Roadway=Roadway, Treatment=Treatment, Concentration=Concentration, cracks=cracks)
groadway <- ggplot(data=crack.data, aes(x=Roadway, y=cracks, fill=Roadway) ) +
  geom_boxplot(show.legend = FALSE) +
  labs(title="Cracks", subtitle="Block (Roadway)") +
  theme_minimal()

gconcentration <- ggplot(data=crack.data, aes(x=Concentration, y=cracks, fill=Concentration) ) +
  geom_boxplot(show.legend = FALSE) +
  labs(title="Cracks", subtitle="Concentration") +
  theme_minimal()

gtreatmeant <- ggplot(data=crack.data, aes(x=Treatment, y=cracks, fill=Treatment) ) +
  geom_boxplot(show.legend = FALSE) +
  labs(title="Cracks", subtitle="Treatment") +
  theme_minimal()

grid.arrange(groadway, gconcentration, gtreatmeant, nrow=1, ncol=3, padding=2.0)
```



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```
summary(
  RCB.model <- aov(cracks ~ Treatment*Concentration, data=crack.data)
)
```

```
##                          Df Sum Sq Mean Sq F value Pr(>F)
## Treatment                 2    452   225.9   0.706  0.498
## Concentration             2     43    21.4   0.067  0.936
## Treatment:Concentration   1    205   205.4   0.642  0.427
## Residuals                54  17278   320.0
```

Exercise 4

Yes, the blocking of roadways was effective in reducing the variability in the number of cracks based on the relative efficiency.

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```
summary(
  RCB.model_ <- aov(cracks ~ ., data=crack.data)
)
```

```
##               Df Sum Sq Mean Sq F value Pr(>F)
## Roadway        4   2899   724.6   2.534 0.0514 .
## Treatment      2    452   226.0   0.790 0.4593
## Concentration  2     43    21.3   0.075 0.9282
## Residuals     51  14584   286.0
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Exercise 5

The assumption of normal residuals was not violated.

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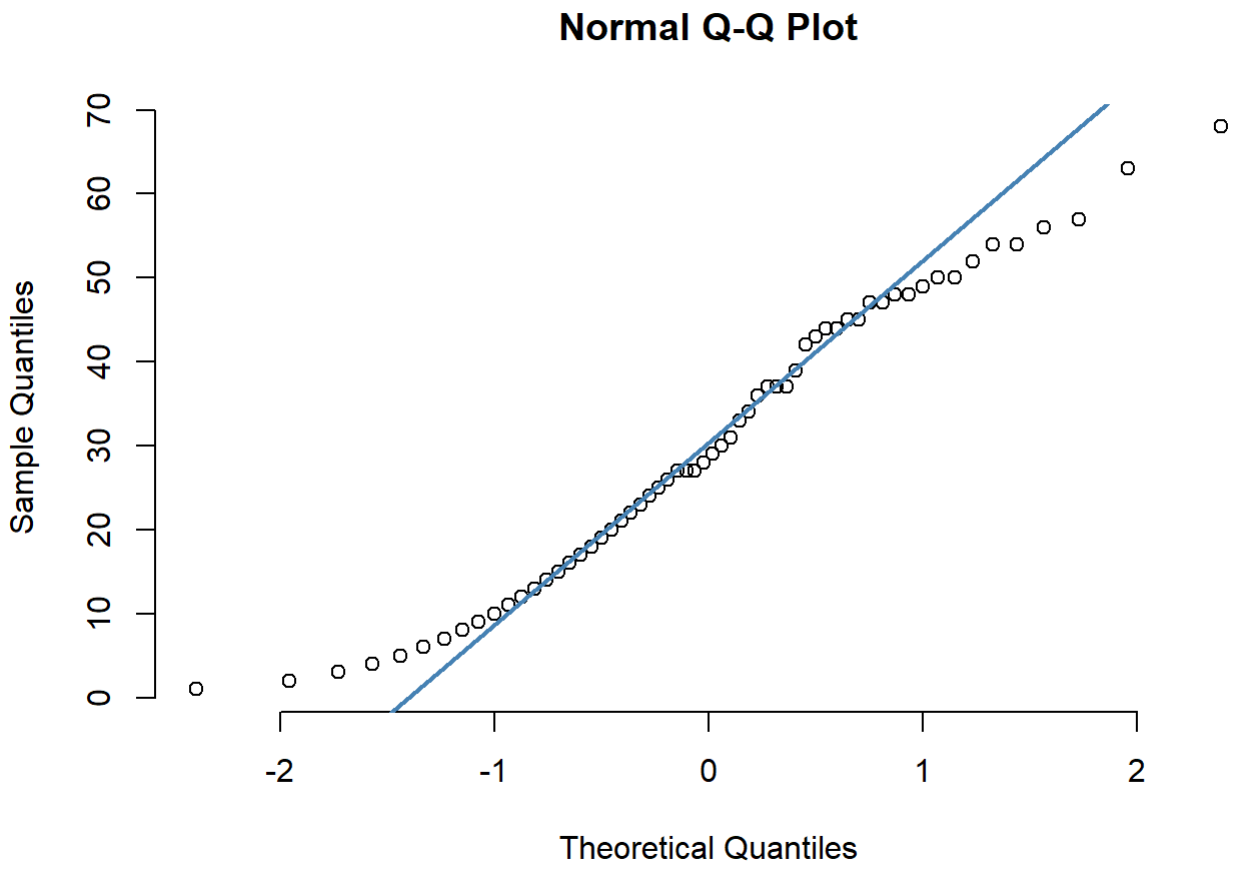
```
qqnorm(crack.data$cracks, pch = 1, frame = FALSE)
qqline(crack.data$cracks, col = "steelblue", lwd = 2)
```



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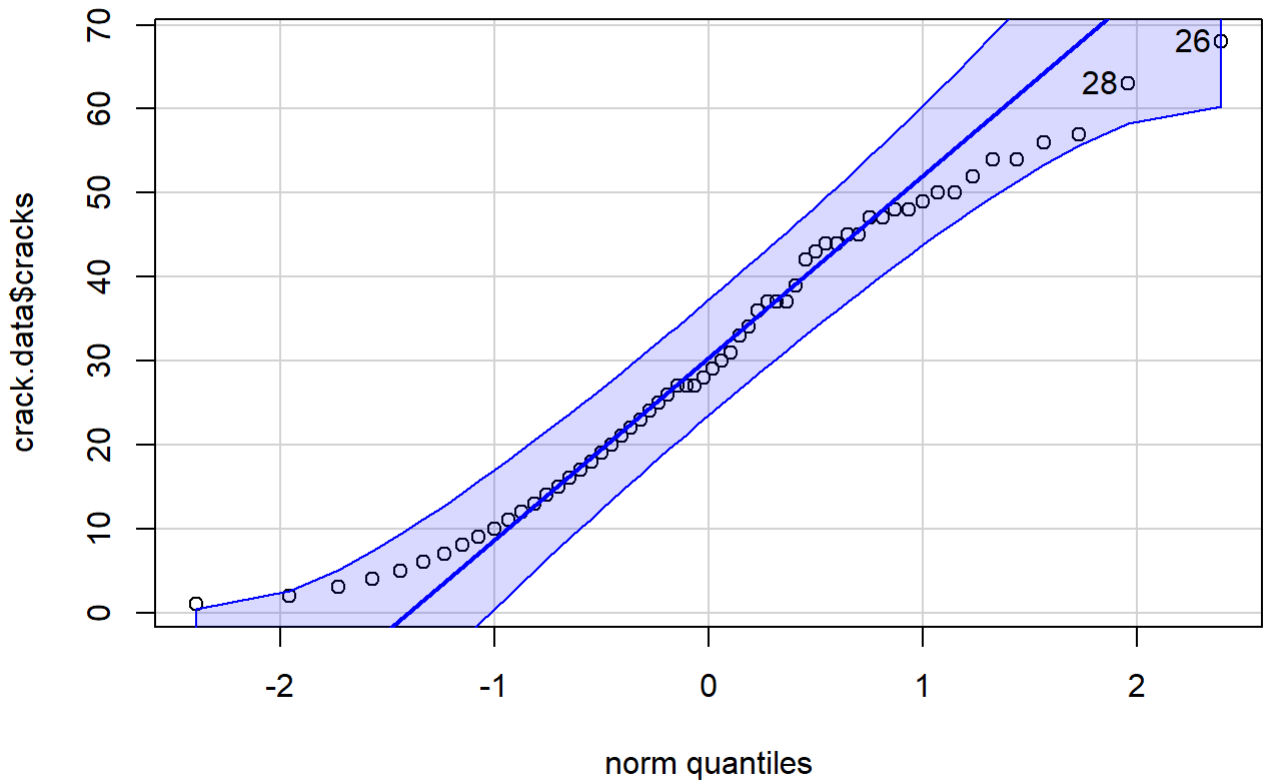
```
qqPlot(crack.data$cracks)
```




```
## [1] 26 28
```

Exercise 6

Treament Sand:med and Concentration NaCl:med results in the fewest new cracks, though it is not a significant difference from the other options.

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```
PostHoc = PostHocTest(RCB.model, which=c("Treatment:Concentration"), method="hsd", conf.level=NA)
PostHoc
```

```
##
##   Posthoc multiple comparisons of means : Tukey HSD
##
## $`Treatment:Concentration`
##          NaCl:low CaCl:low Sand:low NaCl:med CaCl:med Sand:med NaCl:hi CaCl:hi
## CaCl:low 1.00     -        -        -        -        -        -       -
## Sand:low -        -        -        -        -        -        -       -
## NaCl:med 1.00     1.00     -        -        -        -        -       -
## CaCl:med -        -        -        -        -        -        -       -
## Sand:med 1.00     0.97     -        0.96     -        -        -       -
## NaCl:hi  -        -        -        -        -        -        -       -
## CaCl:hi  1.00     1.00     -        1.00     -        1.00     -       -
## Sand:hi  1.00     0.99     -        0.99     -        1.00     -       1.00
```