

A Study of Cracks on Double Storey Houses

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DOI: <https://doi.org/10.30880/rmtb.2021.02.01.060>

Received 01 March 2021; Accepted 30 April 2021; Available online 01 June 2021

Abstract: Cracking is the common defect found on any types of building or house nowadays. This is the serious problem caused by different kinds of causes. The objectives of this research are to identify the types of cracks occur on double-storey houses, to investigate the significant causes of cracks occur on double-storey houses and to investigate the solutions for cracks on double-storey houses. Data collecting was based on the qualitative method. The observation was conducted at the most affected double-storey houses at Taman Lapangan Indah, Ipoh, Perak. Meanwhile, a total of five contractors from Ipoh, Perak were interviewed. The data was analysed using the narrative analysis technique. The main findings indicated that plaster crack, column crack, beam crack, slab crack, hairline crack, and wall surface crack are types of cracks occur on double-storey houses. Nine significant causes of cracks occur on double-storey houses have been confirmed including poor structural design, mixture of ready mixed concrete, change in weather, level of moisture content, poor quality of materials, poor mixture of concrete, quality of cement, poor mortar mix and poor workmanship. The results also showed that crystalline cement, gravity filling, additional reinforcement, re-plaster and surface treatment are the solutions to these issues. Based on these findings, this research suggested that different types and causes of cracks should be investigated earlier and appropriate solutions are needed to adopt immediately. In conclusion, this research mainly to increase alertness among owner of house related on types, causes and solutions of cracks.

Keywords: Cracks, Double-storey, Housing, Ipoh

1. Introduction

According to Rajabather (2017), cracks in the building is a universal issue looked all through the world. The presence of cracks is a symptom of distress within the structure of the building (Chitte, 2018). Besides, cracks may cause negative effects on the building. The occurrence of cracks can reduce the durability, applicability, bearing capacity and seismic performance of buildings (Luan *et al.*, 2017). In Malaysia, it is normal that cracks found in buildings such as cracks appear on the wall or another part of the structure. However, this defect may normally take about 5 to 10 years to manifest

(Tetteh & Mensah, 2016). This defect required high costs for maintenance, poor satisfaction, dangerous to the

buildings and so on. On the other hand, there are various solutions to solve this problem such as by epoxy injection, routing and sealing, stitching and others.

1.1 Research Background

In Malaysia, it is necessary that the occurrence of cracks were found in houses and there are various factors that causes the cracks. In the other hand, the occurrence of cracks in houses is still a major issue in Malaysia. According to Kunal *et al.* (2014), there are some principal causes of occurrence of cracks in buildings such as moisture changes, thermal variations, elastic deformation, creep, chemical reaction, foundation movement and settlement of soil as well as vegetation (Chitte, 2018).

1.2 Problem Statements

In general, cracks are the most common type of problem in any type of building (Chitte, 2018). According to Reddy *et al.* (2018), some types of cracks causes a serious problem and they are to be structurally hazardous. In this research, it is essential to identify types of cracks occur on double-storey houses to prevent structurally hazardous. Chitte (2018) found that cracks may appear due to some causes such as due to moisture changes, elastic deformation, creep, thermal variations, chemical reaction and so on. Besides that, it is also due to some faulty designs and other unavoidable factors. All of the significant causes may lead to different types of cracks. Thus, it is necessary to investigate the significant causes of cracks occur on double-storey houses in this research. Kunal *et al.* (2014) mentioned that the presence of cracks cannot be stopped but some particular measures can be taken to reduce the level and degree of consequences. It seems difficult to have the best solution for cracks. It is important to investigate solutions for cracks on double-storey houses so that the best solutions can be taken to prevent its appearance.

1.3 Research Questions

The research questions of this study are as below:

- (i) What are the types of cracks occur to double-storey houses?
- (ii) How are the significant causes of cracks impact on double-storey houses?
- (iii) How solutions for cracks solve the problem of cracking to double-storey houses?

1.4 Research Objectives

The objectives of carrying out this study are as below:

- (i) To identify the types of cracks occur on double-storey houses.
- (ii) To investigate the significant causes of cracks occur on double-storey houses.
- (iii) To investigate the solutions for cracks on double-storey houses.

1.5 Scope of the Study

This study will conduct mainly focus on the housing area which is limited to the double-storey houses. The scope will be focusing in Ipoh, Perak. This is because presence of sinkhole in the Ipoh area. According to Abd Rashid *et al.* (2015), there are several cases of the sudden formation of sinkholes in the Ipoh areas have been reported. Additionally, some of the geologically derived materials that could lead to building failure and cracks (Mushiri *et al.*, 2018).

1.6 Significance of the Study

The significance of this study are to increase the awareness for owner of house regarding to some types and causes of cracks and also provided solutions for cracks on double-storey houses. Besides, this study provided useful information so that it can be used by contractor to solve the problem related

to cracks on double-storey houses in the future. On the other hand, the significant data that collected in this study is essential for developer as a reference. In additional, this study would be benefit for local authority and also public to create alertness on the types and causes of cracks occur. Lastly, this study is also necessary for academicians as reference and continue for further research.

2. Literature Review

2.1 Types of Cracks in Double-Storey Houses

Typically, cracks can be classified into many types according to time of occurrence, their width and the components of building on which they are developed (Thagunna, 2014). However, there are various types of cracks can be found in a house. For instance, Kunal *et al.* (2014) found that cracks are generally classified to structural and non-structural. These results are similar to those found in research by Chitte (2018) and by More & Hirlekar (2017). According to Reddy *et al.* (2018), some types of cracks causes a serious problem and they are to be structurally hazardous. Therefore, it is essential to identify types of cracks occur to prevent structurally hazardous.

(a) *Structural Crack*

Structural cracks are formed due to incorrect structural and faculty construction which can threaten the safety of a house. Examples of structural cracks are the cracks in beam, column, slabs and footings (More & Hirlekar, 2017).

(b) *Flexural Crack*

Flexure implies twisting, cracks in strengthened concrete beams subjected to for the most part begins in strain zone i.e. delicate of the beam (Reddy *et al.*, 2018). The width of flexural cracks in reinforced concrete beams may remain narrow from the surface to the steel in the short term.

(c) *Torsional Crack*

Usually, beams are subjected to torsion along with bending moment and shear force (Thulasi *et al.*, 2018).

(d) *Tension Crack*

Tension cracks are usually caused by shrinkage or temperature changes. Tension cracks usually occur in those members where restraint is provided in the longitudinal movements (Thulasi *et al.*, 2018).

(e) *Shrinkage Crack*

Shrinkage cracks are commonly caused by a change in the moisture of concrete. This type of horizontal cracks due to evaporation of moisture from the concrete surface in ambient air is created (Kashyzadeh and Kesheh, 2012).

(f) *Splitting Crack*

Splitting cracks are formed in concrete column because of in adequate reinforcement steel and/or inferior concrete quality (Reddy *et al.*, 2018). Otherwise, these type of cracks appeared probably due to load-carrying capacity reaches to its maximum.

(g) *Diagonal Crack*

Diagonal cracks are usually starting from the tension surface of the concrete member. Diagonal

cracks are come in concrete columns because of adequate cross-section and insufficient reinforcement steel (Reddy *et al.*, 2018)

(h) *Horizontal Crack*

Horizontal cracks are in the reinforced concrete column at the junction of beams and columns due to shear forces (Reddy *et al.*, 2018). The horizontal cracks common found high in the wall which probably caused by frost damage.

(i) *Non-Structural Crack*

Non-structural cracks are the result of induced stresses in building constituents and due to internal forces developed because of variance in moisture content, crazing, temperature change and so on. Crack on the parapet wall, wall, the driveway is called non-structural cracks (Thagunna, 2014).

2.2 Causes of Cracks in Double-Storey Houses

Chitte (2018) found that various causes of crack normally are due to moisture movement, thermal movement, foundation movement and settlement of soil, cracking due to vegetation, elastic deformation, movement due to creep and movement due to chemical reaction. However, all of these are the main causes lead to cracks occur on double-storey houses. Besides that, the existence of cracks were also due to some faulty designs and other unavoidable factors. All of the significant causes lead to different types of cracks. Moreover, avoiding the problems of cracking is not easy to achieve. Many designers are trying to eradicate the issues of cracking, but cracking is unavoidable for any structure (More & Hirlekar, 2017). According to Reddy *et al.* (2018), some types of cracks causes a serious problem and they are to be structurally danger. Therefore, it is necessary to identify types of cracks occur on double-storey houses to structural failure.

(a) *Moisture Movement*

Moisture movement can cause significant cracks to occur in building or housing. Otherwise, most construction materials which with pores in the form of intermolecular (Chitte, 2018).

(b) *Thermal Movement*

The cracks caused by thermal movement is either due to external heat, variation in ambient temperature or internally generated heat. This is one of the main important causes of cracking in the building (More & Hirlekar, 2017).

(c) *Elastic Deformation*

Structural components in a building for example columns, beams, walls and slabs, normally consist of materials like steel, masonry, concrete, and others which can undergo elastic deformation due to load (Narwaria & Tiwari, 2016).

(d) *Movement due to Creep*

Some building items such as concrete, brickwork and timber, when subjected to sustained loads not only undergo instantaneous elastic deformation but also exhibit a gradual and slow time-dependent deformation known as creep or plastic strain (Kunal *et al.*, 2014).

(e) *Movement due to Chemical Reaction*

Kunal *et al.* (2014) found that commonly occurring instances of this phenomenon due to sulphate attack on cement products, carbonation in cement-based materials, and corrosion of reinforcement in

concrete and brickwork, and alkali-aggregate reaction.

(f) *Foundation Movement and Settlement of Soil*

Cracks appeared because of foundation movement of a corner on an end of a building and normally diagonal in shape (Chitte, 2018). These cracks are wider at the top and decrease in width downward.

(g) *Cracking due to Vegetation*

According to More & Hirlekar (2017), availability of vegetation in the vicinity of walls can cause cracks in the wall because of the expansion of roots growing across and under the foundation. The cracks occur in clay soil caused by moisture contained by roots (Kunal *et al.*, 2014).

(h) *Shrinkage*

According to Kunal *et al.* (2014), most construction materials expand when absorbing moisture in the atmosphere and shrink when dry. However, shrinkage can be of plastic or dry. (Narwaria & Tiwari, 2016) found that excessive use of water used in the mortar can cause shrinkage in the concrete used.

(i) *Poor Construction Practice*

Poor construction practices is the main issue that leads to the occurrence of cracks on houses nowadays. The construction industry has in generally fallen prey to non-technical persons most of whom have little or no knowledge of correct construction practices (Thagunna, 2014).

(j) *Poor Structural Design and Specifications*

Complex designs using dense reinforcement in slender sections are often lead to poor construction quality. Thagunna (2014) found that the lack of skills and experience of the contractor will eventually lead to the deterioration of the building.

2.3 Solutions for Cracks in Double-Storey Houses

According to Thagunna (2014), suggested that the various techniques to cure crack are for instance epoxy injection, routing and sealing, stitching, drilling and plugging, gravity filling, and overlay and surface treatments. More & Hirlekar (2017) suggested that the various remedial and preventive measures that can be undertaken to solve crack are the use of fine aggregates, use of coarse aggregate, stitching, dry packing, injection of epoxy, plugging and drilling, sealing and routing, sealing cracks with gravity filling, and impregnation of the polymer. Nama *et al.* (2015) also recommend that some techniques cure crack which includes epoxy injection, routing and sealing, stitching, drilling and plugging, gravity filling, dry packing, and polymer impregnation. However, Narwaria & Tiwari (2016) found that cracks in the concrete structures should be served as based on identifying the crack types and if the cracks are dangerous and it should be carefully designed when needed for instance surface filling method, pressure grouting method, caulking method and epoxy resins grout.

(a) *Epoxy Resin*

Epoxy resin injection is an economical method to repair inactive cracks in concrete walls, slabs, columns and piers (Rajabather, 2017). Similar to More & Hirlekar (2017), this method is very useful for repairing dormant or nonmoving cracks in slabs, walls, columns and piers.

(b) *Routing and Sealing*

For this method, the crack is made wider at the surface with a saw or grinder, and then the groove is filled with a flexible sealant (Rajabather, 2017).

(c) *Stitching*

According to Thagunna (2014), stitching involves drilling holes on both sides of the crack and grouting in the U-shaped metal unit, with the short legs (staples or stitched dogs) that span the crack.

(d) *Gravity Filling*

This method it is practically understood that lower the viscosity of the filling the finer the cracks can be easily filled (More & Hirlekar, 2017).

(e) *Overlay and Surface Treatments*

If there is no further significant movement across the cracks, fine surface cracks in structural slabs and pavements may be repaired using a bonded overlay or surface treatment. Unbounded overlays can be used to cover but not definitely repair a slab (Thagunna, 2014).

(f) *Cementitious Grouting*

Cement-based grouts are available in a wide range of consistencies. Therefore, the methods of application are diverse. These materials are the most economical of the choices available for repair (Kunal *et al.*, 2014).

(g) *Drilling and Plugging*

This technique is only applicable if the crack extends in a reasonable straight line and one end can be accessed (Thagunna, 2014).

3. Research Methodology

The research methodology is a set of a systematic technique used in research (Igwenagu, 2016). This simply means research guidelines and methods of conducting. In this research, the researcher implemented the qualitative method by observation and interview.

3.1 Research Design

The research design divided into several phases in this research. Phase 1: Decide on research problem, Phase 2: Frame research questions and objectives, Phase 3: Qualitative method, Phase 4: Data collection method, Phase 5: Qualitative data analysis, and Phase 6: Discussions and conclusions.

3.2 Population, Research Sample and Sampling Method

The target population of this research is Grade 7 registered contractors in Ipoh, Perak which implemented in housing projects. This is because Grade 7 contractors commonly involved in housing projects. According to Rajaprasad (2018), housing construction is commonly implemented or coordinated by contractors who specialize in one type of construction for example residential or commercial building. According to CIDB (2019), the total population size involved 181 Grade 7 contractors in Ipoh, Perak registered under the Construction Industry Development Board. Otherwise, the researcher used purposive sampling to select participants according to the research needs. Thus, only a total 5 of sample size drawn from the total population size.

3.3 Data Collection Method

(a) *Observation (Primary Data)*

Observation has been documented as a tool for collecting data for more than one hundred years (Kawulich, 2014). The observation method was used by the researcher to achieve the research objective 1. This method also used to obtain primary data. In addition to this, the structured and unstructured observation was conducted at the selected double-storey houses. The location was selected at Taman Lapangan Indah in Ipoh, Perak. Additionally, the types of cracks were photographed and all information are recorded by the researcher during the observation.

(b) *Interview (Primary Data)*

This is the most common format of data collection in qualitative research (Jamshed, 2014). While this method was implemented to gain all of the research objectives. In this research, the researcher was done the interview survey form for interview session with five contractors. In addition, the interview survey form was divided into four sections which are Section A: Respondent background, Section B: Types of cracks on building or cracks, Section C: Causes of cracks and Section D: Solutions for cracks. The structured and unstructured interview are conducted by the researcher.

(c) *Library research (Secondary Data)*

Library research is one of the ways to obtain secondary data. The researcher collected data from library materials, including textbooks, published and unpublished books, journals, conference papers and more.

3.4 Data Analysis

Data analysis is a very important part of this research. In this research, the researcher used narrative analysis technique to analyze data collected from observation and interview method. The narrative analysis provides a holistic approach to discourse that preserves context and particularity (Nie, 2017). For this research, the data collected have been classified, analysed and interpreted the information according to the research objectives.

4. Results and Discussion

4.1 Analysis of Results (Observation)

The observation was conducted at the most affected double-storey houses. The location is Taman Lapangan Indah in Ipoh, Perak. This method is necessary to identify the types of cracks appearance on double-storey houses which is the research objective. By observation, the researcher realized some types of cracks appearance on double-storey houses and recorded as information. However, most of the structures of double-storey houses located at Taman Lapangan Indah have occurred various cracks. In September 2020, the double-storey houses were observed by the researcher. Thus, all types of cracks are photographed and all information are recorded in order for further analysis. Based on the observations, the researcher observed that the cracking appeared on the whole structure of double-storey houses. There are significant cracks found on the exterior and interior structure of the double-storey houses. However, the types of cracks observed may refer to the Appendix B.

4.2 Respondent Background

Table 1 shown the respondent background and there are a total of five respondents were interviewed for this research. They are all contractors from Ipoh, Perak which have extensive

experiences and knowledge in housing construction. Besides, they also involved in various housing projects. Most of them have extensive working experience more than 20 years in the construction industry. The interview sessions were done with all respondents to gain all of the research objectives.

Table 1: Respondents background

Respondents	Gender	Age	Working experience in construction industry (Year)
R1	Male	49	25
R2	Male	52	30
R3	Male	49	38
R4	Female	45	23
R5	Male	32	9

4.3 Research Objective1: To identify the types of cracks occur on double-storey houses

Based on the literature review, the researcher mentioned the types of cracks which included tension crack, shrinkage crack, diagonal crack and horizontal crack. The statement “tension cracks are usually caused by shrinkage or temperatures”, was agreed by all of the respondents. Besides that, R4 and R5 have the same opinion that it is caused by temperature changes heat and cool weather in our country. Additionally, R3 said that “yes, tension cracks might happen due to moisture content during plastering, bricks absorbing the moisture from the plastering etc.”

On the other hand, all the respondents agreed that shrinkage cracks are commonly caused by a change in the moisture of concrete. Meanwhile, R5 mentioned that it is due to change in weather, exposure of concrete to the sun and evaporation of moisture from the concrete. Therefore, the moisture concrete might change. Additionally, the incorrect mixture of concrete ratio also might cause shrinkage cracks.

In term of diagonal crack, most of the respondents agreed that diagonal cracks are come in concrete columns because of adequate cross-section and insufficient reinforcement steel (Reddy *et al.*, 2018). There are only two respondents disagreed which are R3 and R5. This is because R3 said that “No, this looks like a structural failure and could be due to design fault or poor workmanship during construction. Further investigation is needed to study the problem before we can be sure of the problem”

According to Reddy *et al.* (2018), horizontal cracks are to be appeared in reinforced concrete column at the beam-column junction due to shear force. Most of the respondents also agreed with the statement. However, only R5 think that most probably due to the foundation problem. In addition, because of foundation unable to support the weight of structure may cause a horizontal crack on wall and column.

In conclusion, it can be summarize that all respondents agreed that tension crack and shrinkage crack occurred on double-storey houses. For diagonal crack, all of the respondents agreed while expect R3 and R5 both of them disagreed. Similar to horizontal crack, all respondents agreed but only R5 disagreed.

Table 2: Summary of types of cracks on double-storey houses

Types of cracks	Respondents				
	R1	R2	R3	R4	R5
Tension Crack	Yes, if the body of concrete is too large and exposed to	Yes, due to poor concrete mixture, incompetent workmanship,	Yes, might happen due to moisture content during plastering.	Yes, caused by temperature changes, moisture	Yes, probably due to moisture level of concrete

	the sun for a long time.	lack of post concreting treatment and curing.		content and level during plastering work.	change, temperature changes hot and cold weather.
Shrinkage Crack	Yes, maybe due to no proper curing and concrete set too fast.	Yes, the poor concrete mixture, incompetent workmanship, lack of post concreting treatment and curing.	Yes, might happens moisture content during plastering.	Yes, cause by the change of moisture of concrete and the mixture of portions cement, sand and water.	Yes, because of change in weather and cause concrete exposed to sun and incorrect mixture of concrete ratio.
Diagonal Crack	Yes, probably structural engineer error and due to poor structural design.	Yes, due to overstressed to the said column and inadequate of concrete strength and reinforcement.	No, this looks like a structural failure and could be due to design fault or poor workmanship during construction.	Yes, the diagonal crack may cause by remix concrete issue and insufficient bar support.	No, due to foundation settlement or probably foundation unable to support the weight of structure.
Horizontal Crack	Yes, due to shear force and anchorage problem between column and beam.	Yes, probably this due to over tension. Sometimes, might due to settlement and soil condition.	Yes, this might one of the factors but many factors affect horizontal cracks, need further investigation needed.	Yes, crack may cause by timing pouring of remix concrete and insufficient of steel bar support.	No, due to the foundation problem. Foundation unable to support the weight of structure.

For the main findings of this research objective, there are total of six types of cracks commonly occur on double-storey houses have been identified which included plaster crack, column crack, beam crack, slab crack, hairline crack, and wall surface crack. According to table 3, R3 and R4 have the same belief that hairline crack commonly occur on double-storey houses. While R3 said that “Normally hairline crack appears on structures due to poor quality control during construction.” Meanwhile, R4 highlighted that hairline cracks are always happening building wall, this may cause when the mixture of material or timing plastering. On the other hand, R1 mentioned that “Plaster cracks are very commonly found on double-storey house nowadays, no matter what types of mortar additive used in Malaysia's market today, still not good, crack still appear.”

Table 3: Summary of main findings for objective 1

Research objective	Respondents				
	R1	R2	R3	R4	R5
RO1: To	Plaster crack.	Column, beam	Hairline crack.	Hairline	Wall surface

identify the types of cracks occur on double-storey houses	Caused by the types of mortar additive used in Malaysia's market today.	and slab cracks. Due to shrinkage, weather and workmanship factors.	Due to poor quality control during construction.	crack. Caused by the mixture of material or timing plastering.	crack. Due to poor mortar mix and materials used nowadays and lack or poor construction practices.
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4.4 Research Objective 2: To investigate the significant causes of cracks on double-storey houses

In general, there are several causes of cracks mentioned in the literature review by the researcher such as shrinkage, foundation movement and settlement of soil, poor construction practices and others. Otherwise, shrinkage is one of the causes of cracks on double-storey houses that has been agreed by all respondents. Otherwise, both R3 and R4 believed that shrinkage caused by the moisture content during plastering. Additionally, R4 and R5 confirmed that our country's weather might be one of the reasons. For instance, R4 said that "Yes, shrinkage caused by weather in our country, moisture content and level during plastering work and controlling of workmanship quality poor nowadays." In contrast, R2 has different point of view that more due to lack of post concreting treatment and curing may result in cracks too.

According to table 4, it showed that there are total of five respondents agreed that foundation movement and settlement of soil is the cause of cracks. R1 explained that "Yes, mostly due to movement of foundation and when double-storey houses built on ex-mining land which can normally found in Ipoh area." Besides, R2 given the opinion that settlement often begins when a double-storey house built on soil that not compacted."

Poor construction practices is the main problem in the construction industry today. This cause might lead to existing of cracks on double-storey houses. Regarding to this cause, it can summarize that five of the respondents agreed with this. Meanwhile, most of them believed that poor construction practices are due to lack of communication. For example, both R4 and R5 pointed that communication is the main reason and R4 said that "nowadays poor construction practices are the common issue due to poor communication between each party such as between project manager and construction worker often lack communication and lead to poor construction."

Table 4 below showed that there are total of five respondents provided their point of view and it can be concluded that all of the respondents agreed that the causes of cracks on double-storey houses are shrinkage, foundation movement and settlement of soil, poor construction practices.

Table 4: Summary of causes of cracks on double-storey houses

Causes of cracks	Respondents				
	R1	R2	R3	R4	R5
Shrinkage	Yes, when plaster wall dried off, the crack will appear.	Yes, more due to lack of post concreting treatment and curing may result in cracks too.	Yes, caused by shrinkage and might happens due to moisture content during plastering.	Yes, caused by weather in our country, moisture content and level during plastering work and controlling of workmanship	Yes, due to the moisture level of concrete change caused by temperature changes hot and cold.

				poor nowadays.	
Foundation movement and settlement of soil	Yes, mostly due to when double-storey houses built on ex-mining land which can normally found in Ipoh area.	Yes, settlement often begins when a double-storey house built on soil that not compacted.	Yes, one of them is the un-even settlement of foundations, but this happens over a long period over a few years.	Yes, but more due to foundation settlement and foundation work is not proper it might cause failure on a whole structure of double-storey house.	Yes, settlement of soil and foundation unable to support the weight of structure may effect on the stability of the structure.
Poor construction practices	Yes, because concrete not properly vibrated on casting, bad bar bending practice.	Yes, some of the construction workers are not told related to proper construction skills.	Yes, it is difficult to ensure that the whole project supervised properly due to insufficient time and cost.	Yes, poor communication between each party.	Yes, because of lack of training among construction workers.

It is important for the researcher to highlight the main findings related to this research objective. The nine significant causes of cracks on double-storey houses have been discovered. There are poor structural design, mixture of ready mixed concrete, change in weather, level of moisture content, poor quality of materials, poor mixture of concrete, quality of cement, poor mortar mix and poor workmanship. For instance, R1 said that “Poor structural design and mixture of ready mixed concrete we are not told. The poor structural design might due to designer lack of experience and skills.” According to table 5, it showed that R2 confirmed that change in weather is the significant causes and R2 explained that “When curing concrete, sufficient moisture is necessary because if the temperature is too high, then evaporation might faster. Therefore, the mix unable to hydrate properly. This might lead to more cracking.” In terms of poor quality of materials, R4 highlighted that quality of cement is the most important material which can lead to cracks happen.

Table 5: Summary of main findings for objective 2

Research objective	Respondents				
	R1	R2	R3	R4	R5
RO2: To investigate the significant causes of cracks occur on double-storey houses	Poor structural design and mixture of ready mixed concrete we are not told.	Change in weather might due to hot and cold weather.	Level of moisture content. This due to moisture content during plastering,	Poor quality of materials, poor mixture of concrete, and quality of cement.	Poor mortar mix and poor workmanship.

4.5 Research Objective 3: To investigate the solutions for cracks on double-storey houses

In this section, the researcher discussed the solutions for cracks on double-storey houses. Based on the literature review, cementitious grouting, epoxy injection and drilling and plugging are mentioned by the researcher. Regarding to this, all respondents provided their opinions. In term of epoxy injection solution, all respondents agreed that epoxy injection is an economical method to repair inactive cracks in concrete walls, slabs, columns and piers. R1 and R4 given the same opinion that this solution is the economical method compared to others. Meanwhile, R1 said that “Yes, still cheaper than grouting but sometimes if cracking stress is too high, the crack will appear again.” However, only one respondent disagreed which is R2 and explained that “No, in term of economic but this is the most effective method to repair cracks in concrete such as column, beam, wall and also slab.”

With the statement "Cementitious grouting method is used for repair of wide cracks", it can said that all of the respondents agreed and R1 said that “Yes, this is one of the ways to solve wide cracks such as wall and slab but this method is expensive compared to other methods.” On the other hand, R2 provided own recommendation that this is because of high pressure therefore suitable to be used for wide cracks.

Moreover, most of the respondents agreed with the statement that “drilling and plugging method is most often used to repair vertical cracks in retaining walls.” Meanwhile, R5 said that “Yes, this method efficient to repair vertical cracks but the process is not easy as crack must be in straight in vertical if not this method might not suitable.” Regarding to this statement, there is only one respondent disagreed which is R2. This is because R2 think that cracks are usually not in a straight vertical line and drill depth, thus it is difficult to achieve.

Lastly, it can be summarize that all of the respondents agreed with the statement regarding to epoxy injection except R2 disagreed. Similar to drilling and plugging, all respondents agreed but only R2 disagreed with the statement. However, all of the respondents agreed the statement of cementitious grouting.

Table 6: Summary of solutions for cracks on double-storey houses

Solutions for cracks	Respondents				
	R1	R2	R3	R4	R5
Epoxy injection	Yes, still cheaper than grouting but sometimes if cracking stress is too high, the crack will appear again.	No, in term of economic but the most effective method to repair cracks in concrete.	Yes, one of the economical method to repair cracks. This method also common used today at site.	Yes, it is an economical method compared to others but it may be lasting for a few years only.	Yes, this method is very useful as it can repair most of the cracks especially on wall, column and slab.
Cementitious grouting	Yes, this is one of the ways to solve wide cracks	Yes, more suitable to resolve wide crack due to high pressure.	Yes, more efficient way to be used especially for wide crack.	Yes, but not quite efficient for wide crack.	Yes, this method is purposely used to repair the wide crack.
Drilling and plugging	Yes, but only used to repair vertical crack but not much recommended due to	No, crack usually not in a straight vertical line and drill depth is	Yes, can solve the problem at the site to reduce cracks but this method is not	Yes, more suitable for vertical cracks therefore this still not efficient to repair other	Yes, but the process is not easy as crack must be in straight in vertical.

expensive. difficult to common. cracks.
achieve.

Besides the solutions discussed above, there are also several solutions for cracks on double-storey houses suggested by all respondents. Table 7 illustrated the main findings of this research objective which related to solutions for cracks on double-storey houses. For instance, crystalline cement is a solution to solve cracks and available in the market. Regarding to this, R1 mentioned that “There is a popular product known as crystalline cement in the market now, this product is easy to use with only apply onto the crack and will grow to seal up the crack if in touch with water moisture suitable for bathroom slab or slab exposed to rain.” Besides that, R3 suggested that additional reinforcement while R4 recommended to re-plaster with demolish existing plaster and re-plaster it for the wall.

Table 7: Summary of main findings for objective 3

Research objective	Respondents				
	R1	R2	R3	R4	R5
RO3: To investigate the solutions for cracks on double-storey houses	Crystalline Cement. This product is easy to use with only apply onto the crack and will grow to seal up the crack.	Gravity Filling. This method is more efficient in term of economic and effectiveness.	Additional reinforcement. Hack the affected area and add reinforcement and re-plaster the whole area.	Re-plaster. This method may need to demolish existing plaster and re-plaster it for the wall.	Surface treatments. More suitable to repair fine cracks on the slab and wall.

4.6 Discussion

(a) *Types of Cracks occur on Double-Storey Houses*

In general, there are four types of cracks on double-storey houses mentioned which are tension crack, shrinkage crack, diagonal crack and horizontal crack have been identified in the interview session. Moreover, these types of cracks mostly found on double-storey house for example diagonal cracks are come in concrete columns because of adequate cross-section and insufficient reinforcement steel. This result was similar to Reddy *et al.* (2018).

Besides, it can said that the main findings of this research objective also have been achieved in this research. There are total of six types of cracks occur on double-storey houses have been confirmed. The types of cracks include plaster crack, column crack, beam crack, slab crack, hairline crack, and wall surface crack. These cracks mostly appeared on double-storey houses. For example, hairline crack probably caused by mixture of material and timing plastering. While wall surface crack might due to poor mortar mix and materials used and lack or poor construction practices.

(b) *Significant Causes of Cracks on Double-Storey Houses*

The second research objective of this research aimed to investigate the significant causes of cracks on double storey houses. Meanwhile, there are causes of cracks occur on double-storey houses which include shrinkage, foundation movement and settlement of soil and poor construction practices have been identified through interview session in this research. These results were supported with the earlier research by Chitte (2018), the research stated that the cracks are normally are due foundation movement and settlement of soil. These results are similar to those found in research by Nama *et al.* (2015) and Thagunna (2014).

Moreover, the main findings for the second objective also confirmed which related to the significant causes of cracks on double-storey houses. There are nine significant causes of cracks on double storey houses have been identified. In reply to that, the results showed that poor structural design, mixture of ready mixed concrete, change in weather, level of moisture content, poor quality of materials, poor mixture of concrete, quality of cement, poor mortar mix and poor workmanship are significant causes of cracks on double-storey houses. These results agree with previous studies, for example, Thagunna (2014) state that poor structural design and specifications is one of the causes of cracks.

(c) Solutions for Cracks on Double-Storey Houses

In this research, the third research objective is to investigate the solutions for cracks on double-storey houses. It can be said that there several solutions for cracks have been confirmed during the interview session. Based on the results, it showed that the solutions for cracks which include epoxy injection, cementitious grouting and drilling and plugging. Besides, epoxy injection is an economical solution for cracks and this result was supported with the previous research done by Rajabather (2017) stated that epoxy resin injection is an economical method to repair inactive cracks in concrete walls, slabs, columns and piers.

For the main findings of this research objective, results from the interview session indicated that crystalline cement, gravity filling, additional reinforcement, re-plaster and surface treatment are the solutions for cracks on double-storey houses. Besides that, the results showed that gravity filling is one of the solutions for cracks. This result is in line with the research by More & Hirlekar (2017) and Thagunna (2014) suggested that the various techniques to cure crack are for instance gravity filling.

(d) Recommendations

Based on the findings of this research, the researcher suggested that several recommendations can be made related to cracks on double-storey houses for further studies. While the recommendations can be made are as the following:

- a) Research on selection of concrete mix components to mitigate cracking on double-storey houses.
- b) Research to address selection of materials in preventing cracks on double-storey houses.
- c) Research on potential solutions to repair cracks on double-storey houses. Research to include crystalline cement, gravity filling, use of additional reinforcement, re-plaster, and surface treatment.

5. Conclusion

This research insight to types of cracks, causes of cracks, and solutions for cracks on double-storey houses. There are various types of cracks are mentioned in this research. However, it can be summarized that the most common types of cracks occur on double-storey house are plaster crack, column crack, beam crack, slab crack, hairline crack, and wall surface crack. Through this research, not only types of cracks have been identified but the significant causes of cracks on the double-storey house also confirmed. The causes are poor structural design, mixture of ready mixed concrete, change in weather, level of moisture content, poor quality of materials, poor mixture of concrete, quality of cement, poor mortar mix and poor workmanship. In case of solutions, it should be adopted appropriate solutions to repair crack which occurs on double-storey houses. The solutions include crystalline cement, gravity filling, additional reinforcement, re-plaster and surface treatment. If proper solutions used, the probable causes of cracks can be controlled.

Acknowledgement

The authors would like to thank the Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia for its support.

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Appendix B



Figure 1: Crack on the column found at the car porch



Figure 2: Cracks on the beam found at the car porch



Figure 3: Crack on the wall found at the living hall



Figure 4: Cracks found above the window



Figure 5: Cracks found on the finishing wall



Figure 6 Cracks found above the door



Figure 7: Cracks found on the floor



Figure 8: Cracks found on above and below the window