Study of properties and strength of no-fines concrete

L JiaHao*, F Chin Lian, Farzad Hejazi and Noor Azline
Department of Civil Engineering, Faculty of Engineering, University Putra Malaysia, 43400 UPM
*jiahaol016@hotmail.com, chinlian0802@hotmail.com

Abstract. Nowadays, special concrete is widely adopted in construction industry. No-fines concrete is one of the special concrete which eliminate the use of fine aggregates in concrete mixing. The application of no-fines concrete has been introduced to construction industry especially pavement construction. Due to its high porosity behavior, the relative density of no-fines concrete is lower than normal concrete of 2400 kg/m³ which also helps in reducing dead weight in the design. In term of strength, no-fines concrete also gave lower compressive strength compared to normal conventional concrete. The aggregate/cement ratio also found to be a factor affecting its strength as it is depending on the interlocking or the strength of bonding between aggregate and cement. Also, concrete with varies mix ratio gives different has been studied for its physical and mechanical properties. In addition, there are further study of introducing fiber materials to determine the chance of enhancement in no-fines concrete study. By elimination of fines aggregates, the development and application of no-fines concrete in the construction industry will be more economical than normal concrete. This paper reviews and studies the performance characteristics and strength of no fine concrete based on previous researcher’s outcome.

1. Introduction
The development of special concrete is increased nowadays as well as the adoption of using special concrete in real world situation such as bio concrete, fibre reinforced concrete, lightweight concrete or no-fines concrete. By studying and developing no-fines concrete would helps economically in saving the limited resources available in the earth.

The adoption of no-fines concrete in the construction industry has been started since early of 1950s. In Europe country, there are successful houses have been built by using no-fines concrete as the material of construction such as Wimpey No-Fines House. One of the reason that it chose to use for external wall of Wimpey No-Fines Houses due to its thermal insulation behavior (Francesca Tittarelli et al, 2013). Also, no-fines concrete also been applied in pavement construction due to its density and porous characteristic which makes no-fines concrete an economical material. Another reason of application in pavement construction is due to its design for minimize pavement surface runoff and stormwater management (Milena Rangelov et al, 2017). Somehow no-fines concrete will not combine with steel reinforcement due to bonding issue unlike normal reinforced concrete. However, if the addition of steel reinforcement is necessary, protection to prevent corrosion of steel reinforcement have to apply (Francesca Tittarelli et al, 2013).

No-fines concrete is a type of special concrete by elimination of fine aggregates in its design mix and made up from interconnected void network in its microstructure (M.Uma Maguesvaria & V.L.
Narasimha, 2013). The size of aggregates used in no-fines concrete mixing are normally range from the size passing through 20 mm and retained on 10 mm on sieve analysis (K Satham Ushane et al, 2013). No-fines concrete has low drying shrinkage properties as there is no fine aggregates in the concrete mix (Nader Ghafoori & Shivaji Dutta, 1998). During segregation happened, the quality of no-fines concrete doesn’t make change as there are no fine aggregates in the mix properties (T. Abadjieva & P. Sephiri, 2000).

Due to porous microstructure, no-fines concrete is expected to have lower density as well as its strength capacity (Shohana Iffat, 2015). No-fines concrete has advantages of having low density which construct to building can reduce in dead weight (Yuwadee Zaetang et al, 2013). No-fines concrete relative density may be much lower if lightweight coarse aggregate is adopted in concrete mix (Ms. K. Prathyusha & Sri. K.Venkateswar Rao, 2016). High ratio of aggregate/cement ratio always give lower density due to bonding issue.

Water cement ratio also one of the factor would affect the workability and porosity during the mixing of concrete (Y. Zhuge and C.Lian, 2009). While if there is high water/cement ratio, the moisture or water in contact with no-fines concrete tends to penetrate and occupy the space in concrete pores which directly affect its relative density when the water dried up (C.Lian et al, 2011). The cement paste will be dry if water/cement ratio is too low and cause insufficient bonding between coarse aggregates (SK.Mohammad Rafi et al, 2014). Size of aggregates also make significant different in porosity due to the surface area of the bonding with cement paste to occur (Md. Abid Alam & Shagufta Naz, 2015).

There is also modification of no-fines by introducing fiber, but it only helps in increasing the compressive strength (Hussam A.A Rehman, 2012). The addition of pozzolana materials such as silica fumes also help to increase the strength of bonding by reducing its permeability of no-fines concrete (Ravindrarajaran et al., 2014). For study of no-fines concrete strength, compressive strength is more concerned as concrete is strong in compression instead of tension. The main reason of adding fine aggregates in concrete is to acts as filler to occupy the pores in the concrete to minimize the movement of moisture or air in concrete to cause expansion and pressure during bleeding. Thus, bonding of coarse aggregates together with cement paste in no-fines concrete will be the main contribution to its strength. Further to the direction of no-fines concrete strength, different mix proportion of no-fines concrete used to check the most suitable design mix that can achieve as high strength as possible (Ghanim Hussein Qoja & Dr. Ali Flayeh Hassan, 2015).

There are a lot of researches and experiment have been conducted to study the characteristics and the mechanical behavior of no-fines concrete throughout the years. However, there are still lacking information to test for no-fines concrete workability such as slump test (Sirile Eathakoti et al, 2015). Therefore, this study will give more direction of applications of no-fines concrete as an alternative eco-friendly material in construction industry.

2. Relative Density of No-Fines Concrete

Few studies have been done to determine the no-fines concrete relative density as it is one of the concern for using no-fines concrete structural design in aspect of self-weight loading. Since the fine aggregates eliminated from no-fines concrete design mix, density of no-fines concrete is expected to be lesser than normal concrete density as normal concrete density range between 2400 to 2500 kg/m3 (Shohana Iffat, 2015).

T. Abadjieva & P. Sephiri, (2000) investigated that concrete density for concrete mixes with different aggregate/cement ratio in mix proportion which ranged from of 6:1 to 10:1 with using 0.45 of water/cement ratio. The result showed that the higher the aggregate/cement ratio, the lower its density will be. The highest density is up to 1880kg/m3 with mix proportion of 6 to 1 aggregate/cement ratio and lowest is 1770kg/m3. Ghanim Hussein Qoja & Dr. Ali Flayeh Hassan (2015) also highlighted that the grading of aggregate directly affects to the concrete relatives density. Similar aggregate/cement ratio as T. Abadjieva's study has been conducted but with different range of water/cement ratio which is from 0.4% to 0.44% respectively. The highest density recorded is 2015kg/m3 for aggregate/cement.
ratio of 6:1 with water/cement ratio of 0.4%. Therefore, it indicated that the density is lower than normal concrete density due to its porous properties.

For further investigation, Hussam A.A Rehman, (2012) studied the enhancement of no-fines concrete properties by introduced carbon fiber. The result showed that the addition of fiber doesn't contribute in its density and the no-fines concrete samples without addition of fiber gave higher value of density up to 1855kg/m3. However, fiber added into no-fines concrete samples did help in increasing its flexural strength, but its compressive strength and density is lower than control samples due to the interlocking issue between mixing materials which are aggregate, cement, water and fiber. Fibers added into samples tend to occupy some spaces in concrete mix and hence weaken the bonding.

With using different type of aggregate, Basher Alam et al, (2012) conducted experiment using bloated slate coarse aggregates to determine the effect of no-fines concrete properties. The mix proportion used in his study varies in aggregate/cement ratio as well as water/cement ratio. Referring to the result from Table 1 below, the highest density recorded is from aggregate/cement ratio of 2.03 with water/cement ratio of 0.44%. The density is gradually decreasing with the increment of aggregates/cement ratio together with water/cement ratio. This is because when there is increment in water/cement ratio used, it will eventually increase the rate of water to occupy the pores within the no-fines concrete samples.

| Samples | Mix Proportion | Relative Density (kg/m3) |
|---------|----------------|--------------------------|
|         | Aggregates/Cement | Water/Cement Ratio |               |
| 1       | 2.03          | 0.44                     | 949           |
| 2       | 2.37          | 0.48                     | 922           |
| 3       | 2.84          | 0.53                     | 866           |
| 4       | 3.59          | 0.55                     | 842           |
| 5       | 4.79          | 0.51                     | 773           |
| 6       | 7.18          | 0.55                     | 740           |
| 7       | 9.37          | 0.59                     | 717           |
| 8       | 14.37         | 0.66                     | 690           |

A.M Muttar, (2013) studied the properties of no-fines concrete and make comparison with the no-fines concrete with and without additional polypropylene fiber. The experiment is conducted with controlling aggregate/cement ratio in range 3:1 to 4:1 and the water/cement ratio in range from 0.31 to 0.35. The result showed that the density of the sample with additional polypropylene fibers has a larger density, due to the reduction of the porosity content in the concrete. The density of sample with aggregate/cement ratio 4:1 also found increased in relative density compared to the no-fines concrete sample with 3:1 ratio due to the increment in the course aggregate content as concrete density majorly contributed by coarse aggregates.

Ikbal N. Gorgis et al, (2018) made comparison for the density test results of the fresh and oven dry for all no-fines concrete samples mixes with using concrete from demolition works as coarse aggregate. The result showed that the fresh density produced higher density which early assumption of particular no-fines concrete properties. It's also an early indication whether the samples can be achieved certain strength like normal concrete. The fresh density achieved the highest density of
1950kg/m³ with aggregate/cement ratio of 5:1. Hence, the porous properties of no-fines concrete, the dry density of concrete gave more concern as water occupied the spaces and pores during mixing of concrete samples and it do affect on its strength as well.

Therefore, density of no-fines concrete can be varying in different mix proportion used during mixing. No-fines concrete definitely has lower density compared to normal concrete due to its porous nature. Water occupied in the concrete pores also one of the factor that cause reduction in the relative density of no-fines concrete. It will left the pore as an empty pore after the remained water is completely dried up.

![Microstructure Schematic Sketch of No-Fines Concrete by Ramadhansyah Putra Jaya et al, (2014)](image)

**Figure 1.** Microstructure Schematic Sketch of No-Fines Concrete by Ramadhansyah Putra Jaya et al, (2014)

3. **Porosity and Void Ratio of No-Fines Concrete**
Porosity of no-fines concrete is one of the physical properties which make significant different compared to normal concrete. The numbers of pores in no-fines concrete gives indication that the weakening of concrete strength. As increase in number of pores, the permeability increases as well. Water tends to flow and occupy the space in concrete microstructure which might directly affect its relative density when the water dried up. (C.Lian et al, 2011).

![Penetration of Water through No-Fines Concrete Samples by Mohammadali Pishdadakhgari (2017)](image)

**Figure 2.** Penetration of Water through No-Fines Concrete Samples by Mohammadali Pishdadakhgari (2017)
The correlation between porosity and relative density of no-fines concrete was observed by Ahmed Ibrahim, et al. (2014). Within the range of relative density used in the experiment, the results showed porosity within no-fines generally decreased as there is an increase in its density. The highest porosity recorded is 38% in the experiment. Hence, the higher porosity also increased water permeability. Most of the researchers are determine the porosity of no-fines concrete by using equation below (Park SB & Tia M, 2004).

$$\text{Void Ratio} = 1 - \frac{\text{(Weight Under Water - Over Dried Weight) x Volume of Sample}}{\text{Density of Water}} \times 100\% \quad (1)$$

Md. Iftekar Alam, (2014) conducted experiment to find out the porosity of no-fines concrete with fixed water/cement ratio and aggregate/cement ratio but using different types of cement. Two types of cement used which are Ordinary Portland Cement (OPC) and Portland Composite Cement (PCC). However, the result showed that porosity of no-fines concrete with PCC is lower than concrete mix with OPC. As pozzolanic reaction occurs for concrete mix with PCC caused the bonding between aggregates and cement increased, thus the pores within the concrete microstructure decreased.

Wen Ten Kuo et al. (2013) found that the porosity in no-fines concrete samples deceased as the void content is reduced by filling with cement regardless the water/cement ratio used in the experiment. Also, porosity of no-fines concrete decreased when high cement content is introduced in the concrete mixtures (Erhan Guneyisi, et al., 2014). The recorded void content in the sample is up to 25%. This is because the void within the samples has been filled with unhydrated cement.

Without manipulating the size of aggregates used in samples or aggregate/cement ratio, the permeability of no-fines concrete are still depending on the void ratio and porosity within the microstructure (Maguesvari & Narasimha, 2013). The porosity of no-fines concrete is significantly reduced when the pozzolanic materials such as silica fumes are introduced into the concrete mixture (Ravindrarajah et al., 2014).

Md. Abid Alam & Shagufta Naz, (2015) studied the properties of no-fines concrete and make comparison with normal concrete. The experiment has been done with fixed mix proportion, aggregate/cement ratio of 7:1 and water/cement ratio of 0.35 but with different aggregate size. Based on his result, the porosity of no-fines concrete samples recorded up to 36% for 20mm size while 10mm aggregates recorded 29% of porosity within the test samples.
which has high impact to strength as well. Therefore, it indicated that porosity of no-fines concrete is affected by size of aggregates.

Amjad A. Yasin (2015) investigated on no-fines concrete porosity with different mix proportion. Based on his result, no-fines concrete samples 4 mix ratio with 12 to 1 aggregate/cement ratio gives the highest porosity up to 17% which also indicated high permeability of the particular concrete as shown in Table 2 below. However, further information of porosity can be studied if the comparison can be made among normal concrete and no-fines concrete.

Table 2. Mix Proportion, Porosity & Permeability of No-Fines Concrete Samples by Amjad A Yasin (2015).

| Samples | Mix Proportion | Porosity (%) | Permeability (mm/h) |
|---------|----------------|--------------|---------------------|
|         | Aggregates     | Cement       | Water/Cement Ratio  |
| 1       | 4              | 1            | 0.4                | 14 | 7717 |
| 2       | 6              | 1            |                     | 11 | 124  |
| 3       | 8              |              |                     | 12.5 | 1633 |
| 4       | 12             |              |                     | 17.2 | 9253 |
| 5       | 4              | 1            | 0.5                | 14 | 6814 |
| 6       | 6              | 1            | 0.5                | 10 | 937  |
| 7       | 8              |              |                     | 16 | 7723 |
| 8       | 12             |              |                     | 11 | 9289 |

L.Korat et al, (2015) investigated the performance of no-fine concrete on different type of aggregate. The experiment materials used various size and shape of coarse aggregates. For further investigation, coarse aggregates are substituted with waste material together with steel slag has to determine the effect in porosity of no-fines concrete as shown in figure 4 below. The result showed that the mixture with steel slag higher density due to it has low percentage of porosity. However, the researcher only limited the aggregate size of 4 to 8mm and 8 to 16mm while the research with difference size can be conducted for further investigation on its properties.
4. Factors Affecting the Compressive Strength of No-Fines Concrete

For every types of concrete, compared to tensile strength, compressive strength is always the main concern to make sure its capacity is sufficient to withstand the applied stress during its life spans. There are few researches have been done with varies mix proportion to study on no-fines concrete strength.

Basher Alam et al, (2012) studied compressive strength of no-fines concrete with bloated slate as coarse aggregates for 28 days. The no-fines concrete samples mixed with Ordinary Portland Cement, variation of coarse aggregates size from 10mm to 40mm and water. The samples is tested with different aggregate/cement ratio and water/cement ratio. 3 samples for each mix proportion tested to obtain the mean compressive strength results. The mix proportion and average compressive strength achieved was shown in Table 3 below.
Table 3. Mix Proportion and Average Compressive Strength at 28 days by Basher Alam et al. (2012)

| Samples | Mix Proportion | Average Compressive Strength (MPa) at 28 days |
|---------|----------------|---------------------------------------------|
|         | Aggregates/Cement Ratio | Water/Cement Ratio |
| 1       | 2.03            | 0.44                              | 2.44       |
| 2       | 2.37            | 0.48                              | 3.39       |
| 3       | 2.84            | 0.53                              | 2.70       |
| 4       | 3.59            | 0.55                              | 1.94       |
| 5       | 4.79            | 0.51                              | 1.32       |
| 6       | 7.18            | 0.55                              | 1.13       |
| 7       | 9.37            | 0.59                              | 0.82       |
| 8       | 14.37           | 0.66                              | 0.41       |

Based on the result, the highest mean compressive strength achieved is 3.39 MPa with aggregate/cement ratio of 2.37. The compressive strength of the samples were mostly increasing as the lower the aggregate/cement ratio been used. The result showed that the lowest aggregate/cement ratio of 2.03 doesn't give the highest strength due bonding failure. For aggregate/cement ratio up to 9.37 and above, the samples encountered the bonding issue since the cement paste cannot fully mixed with bigger volume of aggregates used. Therefore, the result showed that compressive strength of no fine concrete with higher porosity is much lower compared to compressive strength of normal concrete. However, the result obtained is difficult to make comparison as there is no control samples and variation of mix proportion including aggregates/cement and water/cement ratio not fixed.

Ghanim Hussein Qoja & Dr. Ali Flayeh Hassan (2015) also conducted similar experiment to determine the compressive strength of no fine concrete at ages of 7 and 28 days. The studied aggregate/cement ratio is range from 6:1 to 10:1 with water/cement ratio of 0.4 to 0.44 respectively. Referring to the result, no-fines concrete strength increases with its age which is similar to normal concrete (Metwally Abd Allah Abd Elaty, 2015). The optimum strength achieved is up to 9.8 MPa with mix proportion of 6:1:0.4. Also, the recorded compressive strength of no-fines concrete at 7 days are up 60% of strength achieved at 28 days which is quite similar to conventional concrete strength development (V. Patel & N. Shah, 2015). Similar to Basher Alam et al's experiment, there is no control samples which might not able to focus which factors are actually affecting its compressive strength.

Amjad A. Yasin (2015) investigated on no-fines concrete compressive strength at 28 days by controlling water/cement ratio. The aggregate used in the experiment is fixed with range of 2.5 to 2.8 of its specific gravity with low water absorption. 8 samples of no-fines concrete are conducted with two different water/cement ratio in 150mm cubic mold. 4 samples for water/cement ratio of 0.4% and remaining for water/cement ratio of 0.5%. The mix proportion and obtained compression strength at 28 days result are summarized in Table 4 below.
Table 4. Mix Proportion & Compressive Strength at 28 days by Amjad A. Yasin (2015).

| Samples | Mix Proportion | Compressive Strength (MPa) at 28 days |
|---------|----------------|---------------------------------------|
|         | Aggregates     | Cement | Water/Cement Ratio |                                  |
| 1       | 4              | 1      | 0.4                | 3.24                              |
| 2       | 6              | 1      | 0.4                | 8.13                              |
| 3       | 8              | 1      | 0.5                | 5.33                              |
| 4       | 12             | 1      | 0.4                | 0.82                              |
| 5       | 4              | 1      | 0.5                | 3.73                              |
| 6       | 6              | 1      | 0.5                | 8.97                              |
| 7       | 8              | 1      | 0.4                | 1.77                              |
| 8       | 12             | 1      | 0.5                | 1.42                              |

Referring to the compressive strength results on Table 3 above, no-fines concrete samples 4 mix ratio with 12 to 1 aggregate/cement ratio gives the lowest compressive strength which is as low as 0.82 MPa while sample 6 with mix proportion ratio of 6 to 1 aggregate/cement ratio achieved the highest compressive strength which is 8.97 MPa regardless the water/cement ratio. It indicated that the mix proportion can affect the compressive strength directly. The higher volume of aggregates used, the lower the strength achieved. This is because the fixed cement content cannot fully mix all of the aggregates, resulting weak bonding between aggregate with cement and water. For sample 3 and sample 7 with similar aggregate/cement ratio, the strength of no-fines concretes clearly affected by the water/cement ratio. However, further information of compressive strength development can be studied if the experiment result of no-fines concrete compressive strength included strength tested for 7 and 14 days instead of only captured for 28 days. The accuracy of result also can be improved if the number of test samples each mix proportion increase to get mean value of compression strength.

Abdul Malik, (2016) also conducted similar experiment to study the strength of no-fines concrete but with smaller range of aggregate/cement ratio. There are control materials used in the study, which are Ordinary Portland Cement (OPC) as cement, crushed coarse aggregate with angular shaped and its specific gravity of 2.65 and tap water for mixing concrete. 9 samples of no-fines concrete with aggregate/cement ratio of 6:1, 8:1 and 10:1 with water/cement ratio of 0.35, 0.4 and 0.45 respectively are conducted in 100mm cubic mold. The compressive strength obtained is presented in Chart 1 & 2 below.
Based on the result obtained, the compressive strength clearly increased as the water cement ratio increased. The highest compressive strength up to 11.25 MPa is achieved with 6 to 1 aggregate cement ratio with 0.45 of water cement ratio. With lower aggregate cement ratio and high-water cement ratio showed better compressive strength compared to others mix proportion. As aggregate cement paste during mixing is well proportioned, hence its give more compacted cube. The compressive strength of no-fines concrete achieved at 7 days are approximately 2/3 of strength achieved at 28 days. However, the similar mix proportion test sample can be tested to have better comparison and increased accuracy of result by getting mean value of compression strength.

Sirile Eathakoti et al, (2015) also conducted similar experiment as Abdul Malik's experiment but the aggregate/cement ratio is fixed as 8:1. The result outcome showed that the water/cement ratio of 0.45 achieved the highest compressive strength for the concrete compared to 0.35% and 0.4%.

Pravin et al, (2017) studied on the compressive strength of no-fines concrete with adjusting the mix proportion as below table. The compressive strength test is conducted to 150x150x150mm cube. Based on his result, compressive strength of no-fines concrete with aggregate/cement ratio of 4:1 and water/cement ratio of 0.35% has the highest compared to other two mix proportions samples.
Table 5. Mix Proportion & Compressive Strength at 28 days by Pravin et al (2017).

| Samples | Mix Proportion | Compressive Strength (MPa) at 28 days |
|---------|----------------|---------------------------------------|
|         | Aggregates | Cement | Water/Cement Ratio |                        |
| 1       | 4          | 1       | 0.35               | 29.22                  |
| 2       | 6          | 1       | 0.35               | 9.66                   |
| 3       | 8          |         |                    | 5.82                   |
| 4       | 4          | 1       | 0.4                | 10.50                  |
| 5       | 6          | 1       | 0.4                | 4.94                   |
| 6       | 8          |         |                    | 2.50                   |
| 7       | 4          |         |                    | 2.02                   |
| 8       | 6          | 1       | 0.45               | 1.98                   |
| 9       | 8          |         |                    | 1.95                   |

Further to no-fines concrete compressive strength study, Ikbal N. Gorgis et al, (2018) compiled the average compressive strength results at 7 and 28 days. The study used substitution of coarse aggregates with remaining concrete from demolished works and mix proportion of test sample control to 7:1:0.4. The result showed the optimum strength achieved is 8.7 MPa. However, the properties of the aggregates used are not consistent which might affect the accuracy of the results, but the result proved that the compressive strength increased with time.

Therefore, due to the permeability of no-fines concrete, higher water/cement ratio allows higher amount of water penetrates into no-fines concrete through the concrete pores which weaken the bonding strength. Comparing to normal concrete compressive strength, even the highest strength achieved is not suitable to use as structural element for buildings as it is considered low strength and it doesn't help in structural integrity nor capacity.

5. Conclusion

As conclusion, the main focus on physical and mechanic study for no-fines concrete has been studied and reviewed. The relative density of no-fines concrete can be varying in different mix proportion used during mixing. It is gradually decreasing with the increment of aggregates/cement ratio together with water/cement ratio. The range of relative density could be ranged from 1770 to 2015kg/m³ which is much lower than normal concrete density of 2400kg/m³ due to its porous nature. For porosity aspect of no-fines concrete, the volume of void can be affected by size of aggregates. Few results showed that the porosity percentage of no-fines concrete ranged between 27% to 36%. Also, the permeability increased as the porosity increased in no-fines concrete. For mechanical properties, the focus of study in compressive strength of no-fines concrete can be varies depending on the type and size of coarse aggregates as well as the unit weight of no-fines concrete, water/cement ratio and aggregates/cement ratio. The higher the volume of aggregates, the higher the compressive strength of no-fines concrete.

All range of mix proportion gives lower compressive strength compared to normal concrete due to lower density. The optimum compressive strength of no-fines concrete achieved is 11.25MPa which is still considered low strength concrete compared to normal concrete characteristic strength. Therefore, with compiling all the properties of concrete, it is not suitable to acts as building structural member as its capacity to resist stress is low, but it is a good alternative material for pavement as its voids in concrete helps in reducing pavement surface runoff purpose.
6. References

[1] M Uma Maguesvaria & V L Narasimha 2013 Studies on Characterization of Pervious Concrete for Pavement Applications Procedia - Social and Behavioural Sciences 104 (2013) 198-207

[2] K Satham Ushane, K J Pradeep Kumar, and C Kavitha 2014 Investigation of No-Fines Concrete in Building Blocks International Journal of Structural and Civil Engineering Research, vol. 3, no. 4, pp. 170-177

[3] Milena Rangelov, Somayeh Nassiri, Zhao Chen, Mark Russell, Jeffret Uhlmeyer 2017 Quality evaluation test for pervious concrete pavement placement International Journal of Pavement Research and Technology Volume 10, Issue 3, Pages 245-253

[4] Francesca Tittarelli, Maddalena Carsana & Tiziano Bellezze 2013 Corrosion Behavior of Reinforced No-Fines Concrete Corrosion Science 70:119–126

[5] Nader Ghafoori & Shivaji Dutta 1998 Laboratory Investigation of Compacted No-Fines Concrete for Paving Materials Journal of Materials in Civil Engineering 7(3)

[6] Ramadhansyah Putra Jaya, Mohd Ibrahim Mohd Yusak, Mohd Rosli Hainin, Mohd Haziman Wan Ibrahim 2014 A Review of Porous Concrete Pavement: Applications and Engineering Properties IOP Conference Series: Materials Science and Engineering, Volume 226

[7] Yuwadee Zaetang, Ampol Wongsa, Vanchai Sata, Prinya Chindaprasirt 2013 Use of lightweight aggregates in pervious concrete Construction and Building Materials 48:585-591

[8] Ms K Prathyusha & Sri K Venkateswara Rao 2016 Strength and Permeability Properties of No-Fines, Light Weight Concrete: An Experimental Study ISSN 2319 – 6009 Vol. 3, No. 4

[9] Francesca Tittarelli, Alessandra Mobili, Chiara Giosuè, and Maria Letizia Ruello 2013 Sustainable and Durable No-fines Concrete for Vertical Applications International Journal of Chemical, Environmental & Biological Sciences (IJCEBS) Volume 1, Issue 5 (2013) ISSN 2320-4079; EISSN 2320–4087

[10] Sirile Eathakoti, Nayya Gundu, Markandeya Raju Ponnada 2015 An Innovative No-Fines Concrete Pavement Model OSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 12, Issue 5 Ver. III(Sep.-Oct.2015), PP 34-44

[11] C.Lian, Y.Zhuge, S.Beecham 2011 The relationship between porosity and strength for porous concrete Construction and Building Materials 25(11):4294-4298

[12] Mohammad Ali Pishdadakhgari 2017 Pervious Concrete: Potential Advantages in Regions with High Precipitation International Journal of Innovations in Engineering and Science 2(1):16-19

[13] Park S B & Tia M 2004 An Experimental Study on the Water-Purification Properties of Porous Concrete Cement and Concrete Research, 34, 177-184.

[14] Ahmed Ibrahim, Enad Mahmoud, Mohammed Yamin, Virun Chowdary Patibandla 2014 Experimental study on Portland cement pervious concrete mechanical and hydrological properties Construction and Building Materials 50:524-529

[15] S K Mohammad Rafi, B Ambalal, B Krishna Rao and Mohd Abdul Baseer 2014 Analytical Study on Special Concretes with M20 & M25 Grades for Construction International Journal of Current Engineering and Technology E-ISSN 2277 –4106, P-ISSN 2347-5161

[16] M UmaMaguesvaria and V L Narasimha 2013 Studies on Characterization of Pervious Concrete for Pavement Applications International Journal of Advanced Technology in Engineering and Science www.ijates.com Volume No.02, Issue No. 08

[17] R Sri Ravindrarajah, S J. Kassis 2014 Effect of supplementary cementitious materials on the properties of pervious concrete with fixed porosity 23rd Australasian Conference on the Mechanics of Structures and Materials (ACMSM23), vol. I, Byron Bay, NSW, 9-12 December, Southern Cross University, Lismore, NSW, pp. 53-58.
[18] Md. Abid Alam & Shagufta Naz 2015 Experimental Study of the Properties of No-Fines Concrete International Journal of Informative & Futuristic Research (IJIFR) Volume -2, Issue -10, June 2015 2nd Edition, Page No: 3687-3694

[19] Erhan Guneyisi, Mehmet Gesoglu, Qays Kareem, Suleyman Ipek 2014 Effect of different substitution of natural aggregate by recycled aggregate on performance characteristics of pervious concrete

[20] Md. Iftekar Alam, Mir Abdul Kuddus, Shariful Islam 2014 Laboratory Investigation of No-Fines Concrete International Conference on Civil Engineering for Sustainable Development (ICCESD-2014)

[21] Shohana Iffat 2016 Relation Between Density and Compressive Strength of Hardened Concrete Malaysian Journal of Civil Engineering 28(1):50-58 (2016)

[22] T. Abadjieva & P. Sephiri 2000 Investigations on Some Properties of no-Fines Concrete

[23] Rozalija Kozul & David 1997 Effects of aggregate type, size and content on concrete strength and fracture energy

[24] Anush K Chandrappa & Krishna Prapoorna Biligiri 2016 Characterization of Fundamental Properties of Pervious Concrete Paving Mixtures Conference: Transportation Planning and Implementation Methodologies for Developing Countries

[25] Bashir Alam, Mohammad Javed, Qaisar Ali, Naveed Ahmad, Muhammad Ibrahim 2012 Mechanical properties of no-fines bloated slate aggregate concrete for construction application, experimental study International Journal of Civil & Structural Engineering Volume 3, No2, 2012

[26] Muttar A 2013 Improving The Mechanical Properties of No-Fines Concrete Journal of Babylon University/ Engineering Sciences / No.(2)/ Vol.(21): 2013

[27] Wen Ten Kuo, Chih Chien Liu and De Sin Su 2013 Use of washed municipal waste incinerator bottom ash in pervious concrete Cement and Concrete Composites 37(1):328–335

[28] Amjad A. Yasin 2015 Investigation of Mechanical and Physical Properties of No-Fines Concrete International Journal of Engineering Innovation & Research Volume 4, Issue 6, ISSN: 2277 –5668

[29] Ćosić, K., Korat, L., Ducman, V., & Netinger, I 2015 Influence of aggregate type and size on properties of pervious concrete Construction and Building Materials 78 (2015) 69-76

[30] Ghanim Hussein Qoja, Ali Flayeh Hassan 2015 Study of some properties of no-fines concrete using local materials Kufa Journal of Engineering Volume 7, No. 1, P.P.47-53

[31] Metwally abdallah Abd elaty 2015 Compressive strength prediction of Portland cement concrete with age using a new model DOI: 10.1016/j.hbrcj.2013.09.005

[32] Abdul Malik 2016 An Experimental Study on Properties of No-Fines Concrete Imperial Journal of Interdisciplinary Research (IIJR) Vol-2, Issue-10, 2016 ISSN: 2454-1362

[33] Eathakoti, S., Gundu, N., & Ponnada, M. R. 2015 An Innovative No-Fines Concrete Pavement Model IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 5 Ver. III(Sep.-Oct.2015), PP 34-44

[34] V Patel & N Shah 2015 The durability of normal strength concrete: an experimental study WIT Transactions on Engineering Sciences, Vol 90, ISSN 1743-3533

[35] Pravin S Patil, IP. Sonar, Sudhir Shinde 2017 No Fine Concrete

[36] Sh. A. Salih , I.N. Gorgis W.F. Abd 2017 Some Properties of No-Fines Concrete Produced by Using Demolished Concrete as Coarse Aggregates Engineering and Technology Journal Vol. 35, Part A, No. 7, 2017