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The advancement of ceramic waste in concrete

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ABSTRACT

This paper reflects the benefits of ceramic waste in the construction industry. Slump test, the specific gravity of cement, fine aggregate and coarse aggregate including water absorption of aggregates tests are conducted to justify the fresh properties of concrete and are verified. Cubes and cylinders of size 150x150x150mm and 150x 500mm are cast with and without ceramic powder of 10%, 20%, and 30% respectively. In order to get a relative idea about the mechanical properties of concrete, axial compression test and tensile test of cubes and cylinders for 7 days and 28 days of curing in water were done. Sorptivity test has also been conducted to assess the durability of ceramic-based concrete. Test results indicate that the use of ceramic powder in concrete has improved the performance of compression strength as well as in durability.

1. Introduction

Nowadays, there are more and more industries using the ceramic tile in the various types of construction. There are around one hundred million ton of the ceramic tile which are produced from different factories in the world. However, from the total production of the ceramic tile, there is always waste materials which is 20% to 30% of the ceramic (ACIMAC, 2017). Therefore, the development of the concrete technology has a positive impact to the environment due to minimizing the consuming of natural resources. The process of introducing solid waste materials into conventional concrete manufacturing has many advantages, including maintaining the healthy environment in terms of recycle building waste, reducing the negative impact of cement production, and preserving natural materials. This waste also has a beneficial effect in improving concrete behavior and improving its properties. Moreover, there are a lot of advantages of using the ceramic waste powder as partially replacement of Ordinary Portland Cement (OPC) in the mixing concrete. For example, hazardous to the environment is being reduced, saving more energy, and reduction of cost. Thus, ceramic industries are considered as the main source of the ceramic waste powder which can be generate during a verity of process such as from polishing stage or dressing stage. Few studies explained that ceramic waste powder can be replaced either with the cement or with the fine aggregate in the concrete. The advantages of ceramics, many of which are the first material in large quantities and it is high resistance to weather factors and not affected by the sun and water and dust and it has the ability to resist chemicals, making it suitable for all purposes. The ceramic is also characterized by low coefficient of friction and low density and resistance to corrosion is inexpensive and available in abundance. However, the properties of concrete when the ceramic waste powder is replaced with the cement are different from the fine aggregate, especially, the compressive strength and durability of the concrete. The encirclement of the ceramic waste powder in the concrete is extremely beneficial instead of ends to be as a landfill waste. By finding as a solution of the ceramic waste powder which generates from the industries that to be use in the concrete that effects in the durable and compressive strength of the concrete positively as long as the ceramic powder which is not in use at the industry considers one of the harmful waste to the environment. Ceramic waste is usually caused number of drawbacks to the environment. When the ceramic waste which generates from the ceramic industries ends to be a landfill that unfortunately causes hazardous such as air pollution. Thus, that leads to increase the CO_2 emission in the atmosphere and then the global warming effects in a negative way. Usage of Ceramic waste should be possible in various ways; this area alludes to the use of earthenware squanders as

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incomplete substitution of totals. Alves et al. (2014) considered the appropriateness of artistic waste as a conceivable substitute for ordinary coarse totals in the generation of non-structural solid relics and discovered that the fired waste totals can possibly be utilized as a substitution of regular coarse totals however in components where the essential prerequisite is elasticity and protection from scraped area and not compressive quality. Additionally, Senthamarai and Manoharan (2005) also checked the reasonableness of clay squander as substitution of pounded stone total and discovered that the usefulness of fired waste coarse total made cement is great and that the quality attributes are practically identical to that of the traditional cement. Correia et al. (2006) studied the durability of cement made by incomplete substitution of earthenware squanders and discovered that the mechanical properties as far as compressive and elasticity were appropriate anyway because of high water retention possible forceful ecological specialists, for example, injurious salts may enter effortlessly into the solid, which isn't prohibitive in non-strengthened cement. Torgal and Jalali (2011) analyzed the attainability of utilizing clay squanders in cement and their outcomes demonstrate that solid with 20% bond substitution despite the fact that has a minor quality misfortune yet have expanded sturdiness execution, while when concrete blends with earthenware totals indicate preferable outcomes over the control solid blends concerning compressive quality, fine water retention, oxygen penetrability and chlorine dispersion consequently prompting more tough solid structures. Raval et al. (2013a; 2013b) explained using that ceramic waste powder in the concrete is such a beneficial impact to the environment. While the maximum amount of cement is replaced with the ceramic waste powder in the concrete, the will definitely effect in a positive way. For instance, reduction of the consumption resources, use less energy, minimize the CO_2 emission, and the negative impact for the environment will be reduced). Camões et al. (2005) studied on his research about both durability and compressive strength of the ceramic waste based the concrete. The paper is presented the experiment study based on strength properties and durability of the concrete that contain ceramic waste powder. There are a lot of concrete mix that hold a purpose mean of the compressive strength about 30 MPa which prepared as replacement of cement with ceramic waste powder around 20 %. Raval et al. (2013c) conducted an experiment on the eco-efficient concretes by using the powder of ceramic waste as a partial replacement of cement. The ceramic industry generate waste around 15 % to 30 % from the manufacture processes. That waste inevitably poses a negative impact in the future. The study is about replacement of cement with ceramic waste powder in different grades: 0 %, 10 %, 20 %, 30 %, 40 %, and 50 % using the weight of 25M grade of concrete. As loge as the waste of the ceramic powder is inappropriate to sale due to various reasons, therefore, it would be a beneficial solution that the ceramic waste powder is used as a partial replacement of cement in the concrete which will effect positively to the environment and the economy. Several studies have been conducted to test the concrete mixture added to the ceramic waste and compared to the regular concrete mixture. Patel et al. (2015) studied ceramic waste powder from ceramic wall tiles industry is used as replacement to cement in concrete in an incremental order like 0%, 10%.20%, 30%, 40%, 50% and 60% by weight of cement in concrete for M 25 grade. Raval et al. (2013c) suggested the effectiveness of cement replacement with the ceramic waste in order to establish a sustainable concrete. Therefore, one of the most active research areas is waste of ceramic which encompass various disciplines such as construction materials and civil engineering. Powder of ceramic waste results as a pollution to the environment when it is dump away and end of a sediment. The result of that, it may form a dust especially in the summer which will effect negatively for both the public health and agriculture. However, the improvement of ceramic waste powder in different sectors specifically construction, agriculture, paper and glass industries that would definitely help the environment to be protected. So, it is most vital developing an eco-friendly concrete using ceramic waste powder. The study of this research is replacement of cement with ceramic waste powder in various stages: 0%, 10%, 20%, 30%, 40, and 50% respectively using M-20 grade concrete. The mixture of concrete is produced, tested and compared with regard to the compressive strength. The mechanical properties are evaluated in 7 days, 14 days, and 28 days. The achievement of compressive strength is up to 30 % that replaced cement with ceramic waste powder. Raval et al. (2013c) studied about the re-use of ceramic waste from industry in order to elaborate an eco-efficient concrete. The residues production which is from various industries and the construction sectors is increased significantly in the last decade. Unfortunately, most of the ceramic waste is simply thrown in the landfill, and there is no consideration to recycle that ceramic waste or reuse for another purpose. Therefore, the main target of this study is to analyze the mechanical and physical properties for differ concrete mixt that conducted in the lab. Zimbili et al. (2014) studied was on reviewing the usage of the ceramic waste in the concrete production. The demolition and construction waste contribute as the highest percentage of the worldwide waste around 75 %. The highest percentage of the waste in the demolition and construction waste is the ceramic waste which is around 54%. Recently, the method that used for the disposal ceramic waste is only landfill because of the unavailability for standard, lack of the knowledge, risk avoidant, and the construction experience for amount of using the ceramic waste. Around 30% of the ceramic which is produces, goes as waste, therefore, the replacement of cement with the waste of ceramic powder outputs a fundamental amendment in the compressive strength and make them convenient in order to fabric the eco-efficient concrete. So, what is done that the OPC cement is replaced with the waste of ceramic powder consequently in various stages: 0%, 15%, 20%, 25%, 30%, and 35% using grade M-20 weight of concrete. Agrawal (2016) research was based on using the ceramic waste in the concrete. Nowadays, the removal of the ceramic waste is considered as one of the most serious issue around the world. There is a huge amount of materials waste that generate from the process of manufactures, construction, service of industries, solid waste of municipal and demolition work. The awareness to protect the environment is expanding in order to concern about the disposal that the waste is generating from. The management of ceramic waste powder is one of the considerable environmental concern around the world. Meena (2017) advocated the amount of consuming the ceramic materials from the construction industries is increasing every day and it becomes in differ forms such as tiles, electrical insulators, powder, and sanitary fittings. From the total production, 30 % of the ceramic materials is changed to a wastage through the processing or transporting, as it is a nature brittle and recently there is no recirculation for the ceramic wastage. Furthermore, the ceramic waste consists of an excellent mechanical behavior, so it is a suitable for a partial replacement of the cement by using OPC. The ceramic waste powder is passed through 90-micron sieve and then used in the concrete as a partial replacement of cement at 10 %, 20 %, 30 %, 40 % using M25 grade. The concrete mixture is produced then tested and compared as a compressive strength, based on the testes the mechanical and durable properties are evaluated on 7 days, 14 days, and 28 days. Yadav et al. (2017) explained that the cost of the routine materials in the construction is expensive which are coarse aggregate, fine aggregate, cement, and water. This paper of study is consisted the use of differ waste materials as a replacement of cement partially. So, it is vital for developing an eco-friendly concrete from the ceramic waste, especially, ceramic waste powder which end as deposition then only dump away. Study of Jackiewicz-Rek et al. (2015) was about the properties of cement replacement with the ceramic waste. More and more of construction industries are consuming the ceramic and end to left a huge amount of the ceramic waste. The problem is these wastes of the ceramic have a negative impact to the environment and effect badly to the health of human. The study of this paper is obtained the mechanical properties of the concrete when a partial replacement of cement with the ceramic waste powder. So, the result shows that with 20 % of replacement the compressive strength is obtained very high. Hansen (1995) conducted that tensile strength test could directly determine by uniaxial tensile test or tensile splitting test, it show the tension strength of the concrete and the value is very important to show the tension load to the concrete. Tensile strength could evaluated by using formula: $f = \frac{2F}{\pi . l . D}$. Where f the tensile strength in MPa, F is the maximum load in KN, l is the length of the cylinder and D is the diameter of sectional area.

It was noticed from available literature study is that research studies on tensile strength is scarce and the objectives of the research are:

- To investigate tensile strength and compare at different levels of ceramic waste in concrete.
- To determine the optimum percentage of ceramic waste for split tensile strength.
- To reduce the cost of concrete.

2. Methodology

The experiment has been conducted in the lab which is about the replacement of cement with the waste ceramic powder in the concrete. The materials which are used in the research are coarse aggregate, fine aggregate, cement, water and ceramic powder. To determine the work ability and tensile strength of concrete, slump cone test, robe, oil, mixing pan, balance, graduated cylinder, trowel cylindrical moulds and testing machine are used. The experiment is conducted with 0%, 10%, 20%, and 30% replacement with the cement for M30 grade of concrete. The mix proportion is used as 1:0.75:1.5 and the water cement ratio (W/C) is 0.45. Six cylinders and six beams are casted and kept for water curing for 7 and 28 days to determine the tensile strength of concrete

2.1. Materials and their properties and uses

2.1.1. Coarse aggregate

According to the grade of the concrete the size of the coarse aggregate was 20mm and it was collected from MEC lab facility and it was washed and dried, its size had checked by using sieves. The Fig. 1 and Table 1 shows a sample of the coarse aggregate used.

Fig. 1: Coarse aggregate

Table 1: Property of coarse aggregates

Property	Coarse aggregates
Specific Gravity	2.74
Water Absorption	1.45%
Moisture Content	Non-existent

2.1.2. Fine aggregate

Fine aggregate or sand is smaller than coarse aggregate to fill the gaps between them. The fine aggregate used has sieved form 4.75mm sieve and it was clean. Fig. 2 and Table 2 shows the fine aggregate used.

Fig. 2: Fine aggregate

Table 2: Properties of fine aggregates

Property	Fine aggregates
Specific Gravity	2.64
Water Absorption	1.0%
Moisture Content	Non-existent

2.1.3. Cement

Cement is the active component in the concrete, it bonds the other mixture materials together. The used cement was OPC and it was chosen according to the grade of the concrete, it common types used and it gives enough strength to achieve 30M grade. The Fig. 3 and Table 3 shows OPC.

Fig. 3: OPC cement

Table 3: Properties of cement

Initial setting time		180min
Final setting time		240 min
	3 days	37 N/mm²
Compressive Strength	7 days	48 N/mm²
	28 days	59 N/mm²

2.1.4. Ceramic waste powder

The ceramic waste preparation started by collect it from landfills and removes the rubbish from it then it had grinding in the factory to convert it to powder. Sieve test has conducted in the lab to remove bigger size particles. The Fig. 4 shows prepared ceramic powder sample.

2.1.5. Water

Potable water was used in the concrete mix.

3. Test procedure

3.1. Test for compressive strength of concrete cubes

Compressive strength is the most well-known test led on hardened concrete. It is simple and easy to perform and halfway on the grounds that a considerable lot of the alluring properties of cement are subjectively identified with its compressive strength. Take required amounts of material and blended it by hand or by machine blending. Cement ought to be filled in shape in three equivalent layers. Each layer ought to be compacted for multiple times with a tamping rod. After solidified the examples are taken out and relieved in perfect, new water. Restoring is done until the required long stretches of testing. The test ought to be completed quickly upon the expulsion of example from water restoring and after that discovering the compressive strength by compressive machine:

$$Compressive\ strength = maximum\ load/area\ = P/A.$$

3.2. Slump test

The test had started by set up the slump test cone by clean it then its internal side was painted with oil, the cone was fixed to the base sheet. The fresh concrete was filled into the cone in three layers and it was tamped 20 times by using steel bar for each layer as shows in Fig. 5 and Fig. 6. After that the cone was released up and flipped up to down and placed nearby the collapsed concrete cone and the reading of different length between the steel bar and the top of the concrete cone is measured and recorded.

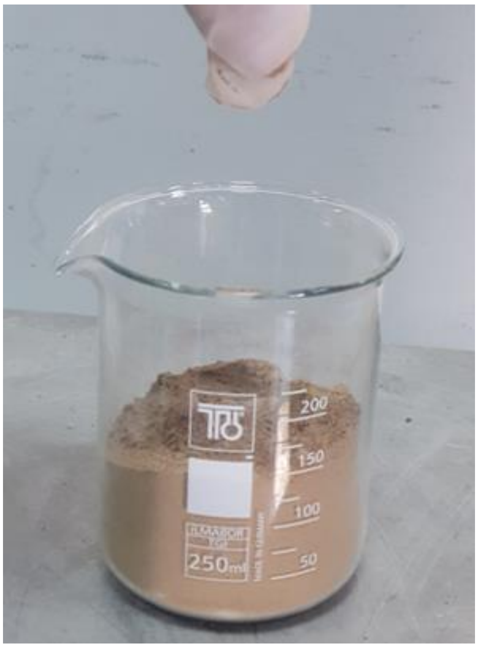

Fig. 4: Ceramic powder

Fig. 5: During slump test-filling slump cone

Fig. 6: Measuring slump

3.3. Slump test values guides

According to BS EN 12350-2, The Value that was taken from the slump test is the different in length between the length of steel cone and the length of concrete cone and it shows the workability level and uses as shown in the Table 3 and Table 5, and by observe the shape of concrete the types of slump is found Fig. 7 shows the shape and type of the concrete (Singh and Srivastava, 2018).

4. Results

- Compression test results: Compressive strength result was shown in Fig. 8.
- Tensile strength results (Table 4)
- Slump test results (Table 5)
- Sorptivity results: Sorptivity of the cubes immersed up to 10mm in water are shown in Fig. 9.

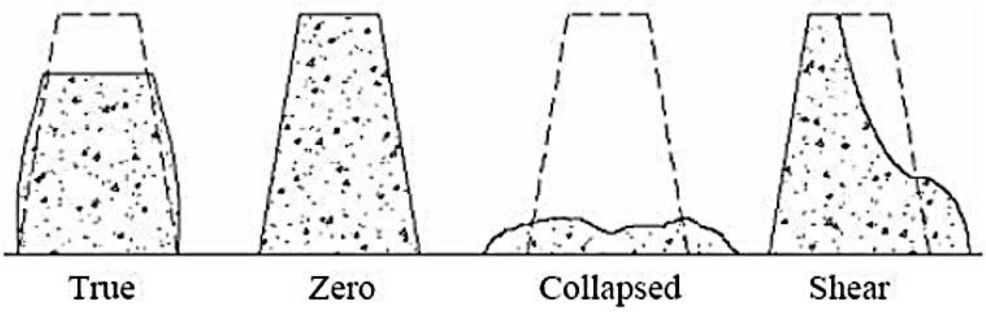

Fig. 7: Types of slump

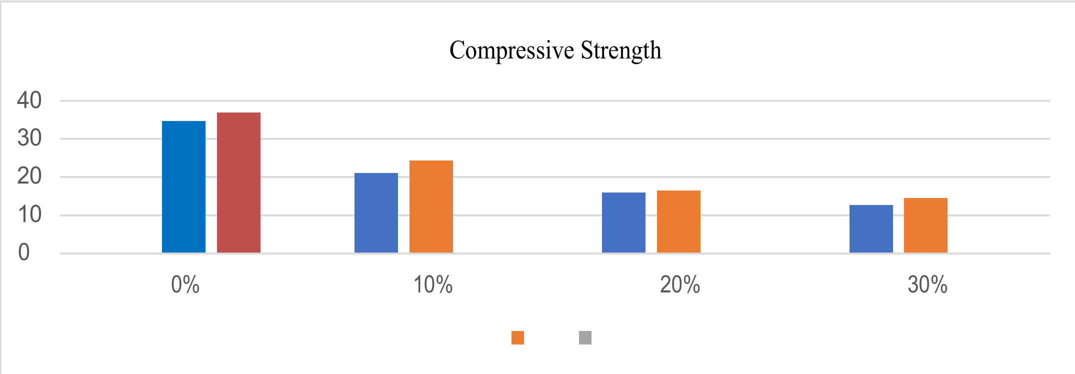

Fig. 8: Compressive strength result

Table 4: Tensile strength results

Concrete age (days)	Cylinders			
	0%	10 %	20%	30%
7	4.4	4.95	5.08	3.98
28	4.63	5.3	5.63	4.23

Table 5: Slump test results

Replacement %	0%	10%	20%	30%
Length of Collapse (cm)	10.5	5.8	3.5	1.5

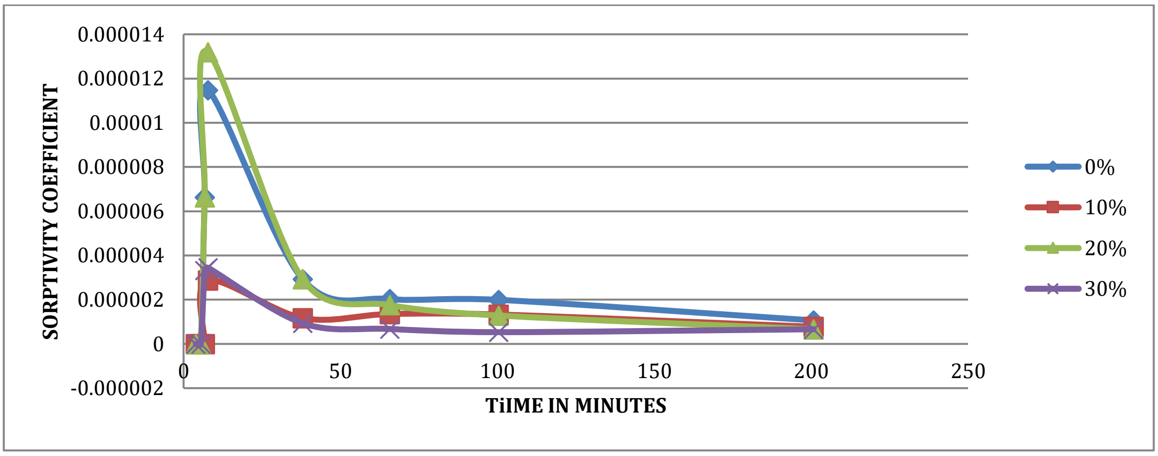

Fig. 9: Sorptivity of the cubes immersed up to 10mm in water

5. Discussions

The compressive strength tests were performed on the compressive test machines. The test was done on three cube samples size 150mmX150mmx 150mm for each percentage of the concrete mixing percentages and the average values recorded above were taken in Fig. 8. The study was conducted to compare the concrete properties of concrete mixing ratio 1: 0.75: 1.5 with a partial replacement of cement with ceramic powder by 10%, 20% and 30%. Various standard codes recommend concrete cube as the standard specimen for the test. So, according to BS 1881: Part 116: 1983 standard the compressive strength for 28 day curing it should be more than 85% resistance broking.

The results showed that the when increase the percentage of replacement of ceramic waste from 10% to 30% the compressive strength of the concrete become less. As time and days, we note that the values increase in strength as the value of the compressive strength of the sample in 7 days at 30% replaced increasing with 28 days curing, as the greater the number of days the stronger the strength of the concrete. These results are due to several factors, including the ratio of water in the mixture, the quality of the materials used in the mixing, and the quantity of the chemical elements in the materials

5.1. Tensile test discussion and analysis

Based on the Table 4; test results are shown that 10% and 20% replacement achieved higher values compared to 0% and 30% of cement replacement. The average results of specimens are shown in the Table 4. The use of ceramic powder in concrete increases with increase in tensile strength and 20% is optimum. Beyond 20% it is observed that there is in reducing strength properties

5.2. Slump test discussion and analysis

Regarding the slump test results shows in the Table 5, overall results are fluctuated. At 0% is 10.5 cm but the results of the remaining percentages of replacement are all less than 6 cm and it means the workability in 0% and 10% is higher than other percentages.

5.3. Sorptivity analysis

In the present investigation Sorptivity tests were conducted on cube specimens i.e. with w/c 0.5 on 150*150*150mm cube moulds. The weight recorded at the end of different intervals is noted down and sorptivity is calculated. The results are tabulated in Fig 9. A general observation from Table 6 is that Sorptivity decreases with addition of ceramic powder when compared with conventional concrete This shows ceramic powder in concrete up to 30 % replacement is better than conventional concrete.

Table 6: Sorptivity coefficient vs time^0.5

% of ceramic powder	Wt. of concrete	15min	30min	45min	60min	24hrs	3days	7days	28days	% increase in wt. for 28 days
0	8.900	8.90	8.90	8.91	8.92	8.925	8.930	8.945	8.948	0.536
10	8.670	8.670	8.670	8.67	8.675	8.68	8.69	8.70	8.705	0.516
20	8.500	8.50	8.50	8.510	8.523	8.525	8.526	8.529	8.530	0.468
30	8.450	8.450	8.450	8.455	8.456	8.458	8.460	8.462	8.468	0.412

6. Conclusion

Based on the experimental study on investigating work ability and tensile strength of concrete with partial mix of ceramic powder with cement in different levels conclude that:

1- The preparation of the concrete is completed accordingly to each percentage of cement replacement and then tasted based on the duration period.
2- The result of the tensile test of concrete strength shows that when the percentage of cement replacement is increased, the tensile strength of the concrete is increased up to some extent and reduced.
3- The best result of tensile test has achieved at 10% and 20% of replacement which is 5.3 and 5.63 MPa after 28 days of curing in the water.
4- The lowest result of tensile strength is obtained at 30% of cement replacement to reach only 4.23 Mpa after 28 days of curing in the water.
5- Using the ceramic waste powder in the concrete as a partial replacement of cement pose various advantages such as reduction of concrete cost and less waste of landfill on the environment.
6- Hence, it can be concluded that effect of ceramic powder on concrete is good enough to satisfy the requirements for compressive strength, tensile strength and Sorptivity.

7. Recommendations

Our recommendations for using ceramic waste in the manufacture of concrete in proportion to the replacement of 10% regarding the control of quantity and weights and mixing well to obtain the correct results because these wastes are a threat to the environment and must be disposed of in a way that can be used. Also, We encountered some errors and difficulties in the practical application of the experiment, in terms of the difficulty of providing materials, especially ceramic waste in the process of grinding also when mixing the ingredients we encountered difficulty in mixing because the quantity is large as well as the test time was not available in the time specified for the test work also there is not enough space to save the cubes in Water, so we could not achieve the expected results due to inadequate conditions in terms of materials, tools and space.

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Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest.

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